

Practical treatise on milling and milling machines

Brown & Sharpe Manufacturing
Company (Providence, R.I.)

ENGINEERING

7621.91

B815

cop. 1

Columbia University
in the City of New York

LIBRARY









Practical Treatise
on
Milling
and
Milling Machines



1919 Edition

BROWN & SHARPE MFG. CO.

PROVIDENCE, R. I.

U. S. A.

Copyright, 1914, by Brown & Sharpe Mfg. Co., Providence, R. I.



THE business now conducted by the Brown & Sharpe Mfg. Co. was founded in 1833 by David Brown and his son, Joseph R. Brown. David Brown retired in 1841, and the business was continued by Joseph R. Brown until 1853, when Lucian Sharpe became his partner, and the firm of J. R. Brown & Sharpe was formed. The Brown & Sharpe Mfg. Co. was incorporated in 1868.

The works are situated one-half mile from the business centre of Providence, and are within a few minutes' walk northwest from the railroad station.

The buildings are modern, and especially arranged to meet the requirements of the business. The seven main manufacturing buildings have a floor space of about 740,000 square feet; the foundry building about 245,000 square feet; the forging, hardening, central power plant and miscellaneous buildings about 215,000 square feet. In 1853 the floor space occupied was 1800 square feet; the present buildings have about 1,200,000 square feet of floor space, or over 27 acres.

We are always glad to show visitors through our works.

Engineer

D 621.91

B 615

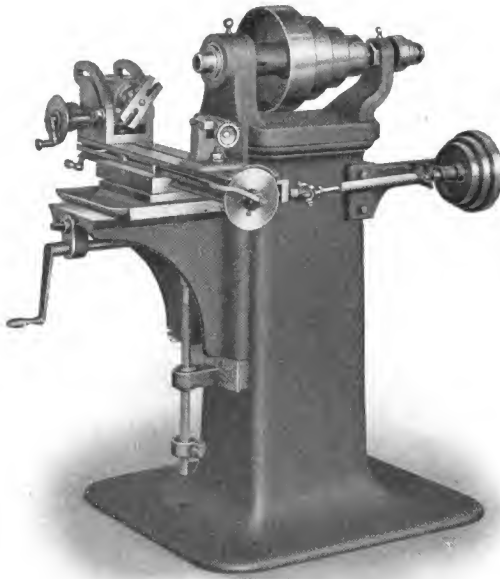
copy 1

PREFACE

It is our purpose in publishing this book to present, in as non-technical a manner as possible, information that will assist the beginner and practical man to a better understanding of the care and various uses of modern milling machines of the column and knee and manufacturing types.

CONTENTS

CHAPTER I	Page
Classification of Milling Machines	11
CHAPTER II	
Essentials of a Modern Milling Machine	21
CHAPTER III	
Erection and Care of Machine	37
CHAPTER IV	
Spiral Head—Indexing and Cutting Spirals	47
CHAPTER V	
Attachments	69
CHAPTER VI	
Cutters	89
CHAPTER VII	
General Notes on Milling, together with Typical Milling Operations	107
CHAPTER VIII	
Milling Operations—Gear Cutting	149
CHAPTER IX	
Milling Operations—Cam Cutting, Graduating and Miscellaneous Operations	177
TABLES	209



The Original Universal Milling Machine

The original universal milling machine was designed primarily for the purpose of forming the flutes in twist drills. Its wonderful capabilities, however, were quickly recognized, and its use soon spread to other lines, until today we find that there is an unusually large variety of machine shop jobs that can be done on a modern machine of this type. Straight and angular pieces, and surfaces of an endless variety of irregular contours, together with spur, bevel and spiral gears, twist drills, etc., can be produced. Also such work as drilling, boring, planing, rack cutting, slotting, cam cutting, graduating, etc., can be successfully accomplished. In fact, the full variety of work that can be done on a universal milling machine is still unknown, for new ways of using it are being constantly discovered.

INTRODUCTION

Milling is the process of removing metal with rotary cutters. It is employed extensively in machine shops today for forming parts of machinery, tools, etc., to required dimensions and shapes. A machine designed especially for this purpose was in existence as early as 1818, but little progress was made in the process until after the invention of the universal milling machine (shown on the opposite page) in 1861-62 by Mr. Joseph R. Brown, of J. R. Brown and Sharpe. This was owing chiefly to the difficulties of obtaining satisfactory cutters and of sharpening them. Shortly after this, however, improvements in the methods of making cutters, the invention by Mr. J. R. Brown of the formed cutter which can be sharpened without changing the cutting contour, and the introduction of the grinding wheel for sharpening cutters removed the obstacles that had so seriously hindered the early development of milling.

As the field of milling widened, the demands upon the machine increased accordingly, and it became necessary to make certain improvements to adapt it to the new conditions. But it is a noteworthy fact that in all of the changes in design leading up to the modern heavy type of universal machine, shown on page 44, none of the fundamental ideas of the original machine have been lost. Parts have been strengthened to better withstand heavier service, and radical changes have been made in the method of driving the spindle and feeds to accommodate the machine to modern requirements.

From a comparison of the original machine with a modern type, the important changes that have been made are readily noted.

The column has been carried well above the spindle, and an overhanging arm with a support for the outer end of cutter arbor has been added. To further stiffen the arbor, arm braces have been devised by the use of which the overhanging arm, cutter arbor, and knee are all rigidly tied together. These braces on the smaller sizes of machines consist of long slotted cross arms, while on the larger, or heavy service machines, a different and heavier type is employed.

The table feed has been changed from the end of the feed screw and carried up through the centre of the knee and saddle, thus allowing the table to be swiveled through a much greater arc. Power feeds have been applied to the transverse and vertical table movements, and on large machines a power fast travel for the table has taken the place of the hand quick return. The old-style elevating screw for the knee that required cutting a hole through the floor has been replaced by a telescopic screw.

Improvements have been made on the spiral head to make it more rigid and convenient to operate; differential indexing largely replaces the compound method, and refinements such as graduated index sectors, and an adjustable index crank have been added.

Such conveniences as permanent handwheels instead of cranks, adjustable dials reading to thousandths of an inch on the feed shafts, and other improvements have been added from time to time.

When the milling machine came into more general use, and its possibilities in removing metal began to be appreciated, the demand arose for the ability to make heavier cuts. These demands soon demonstrated that the method of driving the feeds through belts and cone pulleys from the spindle of the machine to the feed mechanism, was inadequate. The first improvement was to substitute chain and sprockets for the belt and pulleys and to use removable change gears to provide a variation in the rate of feed. The next step was to place all the change gears in a feed box wherein by simply shifting levers, a wide variation of feeds could be obtained.

The main spindle drive has undergone radical changes. The original machine had a four-step cone pulley mounted directly on the spindle, and many of the smaller sizes of machines today are similarly built. In order to get more power and a greater range of speeds, back gears similar to those of a lathe were added.

Following these improvements came a radical change in the whole driving mechanism of the machine. The value of feeds that were independent of the spindle speeds had become well recognized, and with the introduction of high speed steel, from which cutters could be made that would take much heavier cuts at faster speeds, and coarser feeds than had ever before been the practice, there arose a demand for more powerful machines. The constant speed type of drive was therefore originated. In this type of machine any combination of table feed and spindle speed is available, because both spindle and feeding mechanisms are driven from the main shaft of

the machine, which revolves at a constant high velocity at all times. The table feeds are therefore entirely independent of the spindle speeds. A powerful drive is also transmitted to the spindle from the driving pulley of large diameter and wide face on the main shaft of the machine through a train of heavy spur gearing in which are certain change gears that can be manipulated to give a wide range of spindle speeds.

At the same time that the constant speed type of drive was evolved, the machine was redesigned and made stronger throughout in order to better fit it for the heavy cuts that had become the practice.

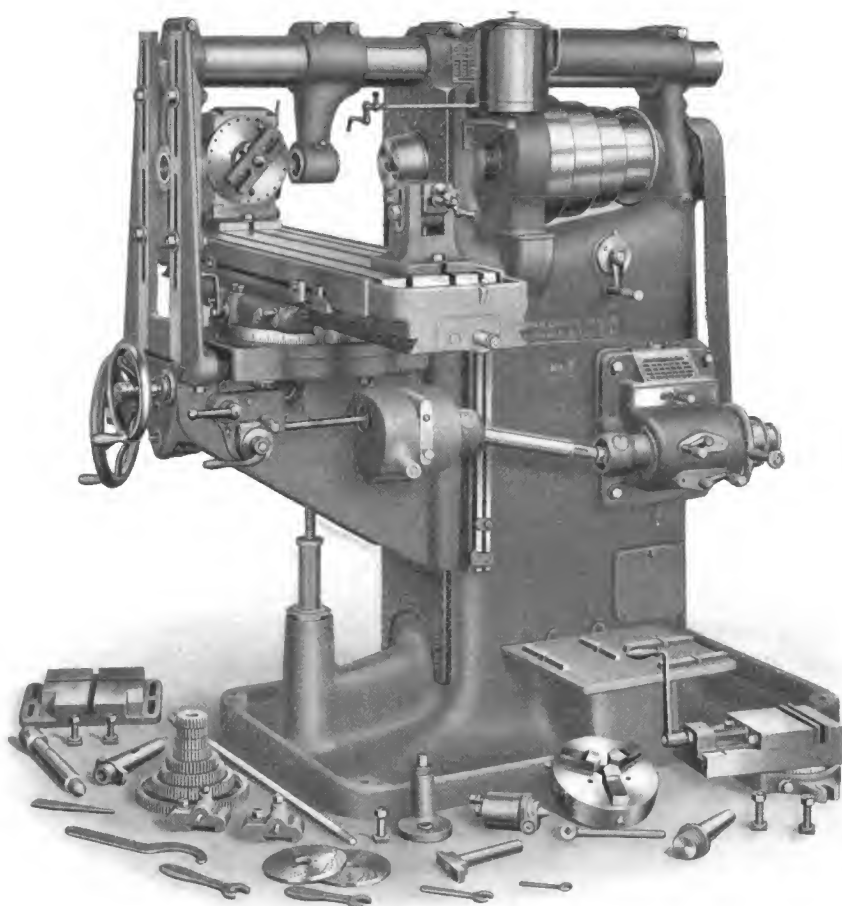
Later improvements have been the extension of the flat bearing surface on the front of the column to the top, the application of a friction clutch in the driving pulley with levers at the sides of the machine for operating it, the power fast travel for quick movement of the table, and other improvements of lesser importance.

It is not to be assumed that the constant speed type of drive has been developed to the exclusion of the cone type, for there are many pieces of work that can be done to good advantage on this machine. The modern cone type of machine embodies all of the previously mentioned improvements, except those relating particularly to the constant speed drive, and there is still, and probably always will be, a steady demand for this machine.

Two other types of machines known as Plain and Vertical Spindle Milling Machines have kept pace with the development of the universal machine.

Milling Machines of the Planer and Manufacturing types have also come into extensive use, the former producing a wide range of work that is of too large dimensions for the previously mentioned machines, and the latter manufacturing in large quantities, small duplicate parts of machinery, tools, etc.

With the improvements that have been made on the machines and their equipment, milling has become indispensable in the modern shop. Interchangeable pieces can be easily made, and work is produced at a low cost because of the continuous operation and inexpensiveness of cutters for a given amount of production. We, therefore, recommend the milling machine to manufacturers desirous of obtaining the best results at the lowest cost on all classes of work to which the machine is adapted. And we trust that a careful reading of the following chapters will be of material assistance in understanding the process of milling and how to use the machines.



Column and Knee Milling Machine of the Universal Style, Cone Drive

CHAPTER I

Classification of Milling Machines

The existing types of milling machines are so numerous, and their designs merge into one another to such an extent, that it is very difficult to classify them definitely. But, taken as a whole, they may be said to consist of two distinct groups, those adapted to a variety of work, and those restricted to the performance of a single operation, such as gear cutting, bolt head milling, thread milling, etc. While this latter group embraces some valuable and interesting machines, the class of work done is of a more or less special character, and little can be learned from it of the general process of milling. For this reason, and also from the fact that it would be practically impossible to treat of every type in the limited space of this book, the first group alone will be considered. The machines of this group are classified in a variety of ways by different writers. We prefer to divide them, according to general appearance and design, into three classes, comprising the column and knee type, manufacturing type, and planer type. Such a classification brings out the characteristics of the different machines, and their relation to one another.

Column and Knee Milling Machines

An illustration of a representative example of the column and knee type of milling machine is shown on the opposite page. This machine is the most recent of the three types named, having been in existence about fifty years. The rapid strides, however, that have been made within the past few years in the process of milling are largely due to its versatility and convenience. Even with the most expert cutter making, milling could never have obtained its important position in the field of machinery and tool manufacture had it not been for the column and knee type of construction.

The name, column and knee, is derived from the high, column-like design of the main casting, and the likeness of the bracket which supports the table to a knee or angle iron. The knee is adjustable on the column so that the table can be set at different heights to accommodate work of varying size. It can also be fed upward,

thus enabling vertical cuts to be taken. Provision is made for movement of the table horizontally in two directions: one, longitudinally, at right angles to the axis of the spindle; and the other, transversely, parallel to the axis of the spindle. The combination of these three movements is found only in the column and knee machine, and it is due to the advantages derived from this construction that the machine is superior to the manufacturing or planer type for general milling purposes.

Several more illustrations of column and knee machines are shown on succeeding pages of this chapter, where a further classification is given.

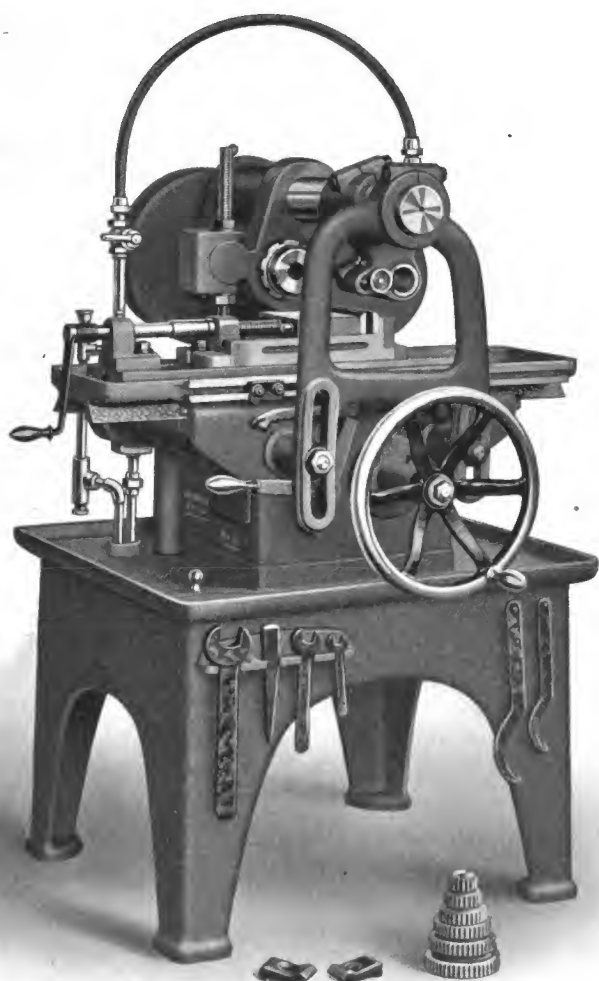
Manufacturing Milling Machine

This type of milling machine is shown in the illustration on the opposite page. It is a development of one of the earliest forms that was built particularly for use in the manufacture of small parts of firearms, and has since been successfully adopted for machining parts of sewing machines, typewriters and other machines and tools. The advantages it offers for this class of work are due to the stiff construction and convenience with which it can be operated. These make possible an exceptionally large production of first quality work—factors of great importance in commercial manufacturing.

There are many minor variations of this type of milling machine, but the general features are similar in all. In that shown on the opposite page, the spindle is supported in bearings located in an adjustable head that can be raised and lowered. The capacity of the machine is rather limited as regards work of widely varying heights. Furthermore, there is no transverse table feed, the only movement transversely being obtained by a slight adjustment of the spindle. These, however, cannot be considered disadvantages, as provision for work of widely varying heights is not required, because all work done is of comparatively small dimensions, and there is seldom any necessity for a transverse table movement.

The longitudinal movement of the table is at right angles to the axis of the spindle. This movement is accomplished either automatically or by hand by means of a rack and pinion on the under side of the table. The pinion is driven from the spindle through a train of change gears and a worm and wheel when the automatic feed is in action.

A larger and improved style of manufacturing machine is shown on page 88. It embodies all the features of the machine illustrated



Milling Machine of Manufacturing Type

on page 13, but in addition is designed so that the spindle is more powerfully driven and has a greater vertical adjustment. The table is also provided with a transverse movement. This machine is therefore adapted to a somewhat wider range of work than the one previously described.

Planer Milling Machine

The planer milling machine is designed for the heaviest classes of slab and gang milling. It bears a marked resemblance to the planer, from which it derives its name. The spindle is mounted in bearings carried in a vertically adjustable slide similar to that of a planer, and the table is in a corresponding position. This brief reference will enable one to easily distinguish these machines. And, as the class of work performed is identical in character, only heavier than that done on the column and knee type of machine, the same principles are involved.

Returning to the column and knee type, we can subdivide it into three classes, known as Plain, Universal, and Vertical Spindle Machines. In the first two the spindle is supported in horizontal bearings that are fixed in the main casting of the machine instead of being adjustable vertically, as in the case of both manufacturing and planer types of machines. This is one of the points where the column and knee machine is radically different from either of the other types. As we have already explained, vertical adjustment in this type is obtained by the movement of the knee upon the column. In the vertical spindle machine, the spindle is supported in vertical bearings, vertical adjustment being obtained by the movement of both the knee and spindle.

Plain Milling Machine. The word **plain** when applied to any milling machine is used to designate one in which the longitudinal travel of the table is fixed at right angles to the spindle. Both manufacturing and planer types are therefore essentially plain milling machines.

An illustration of a plain milling machine of the column and knee type is shown on page 19. In this machine, the table has the three movements: longitudinally, transversely, and vertically, that have already been mentioned. Some machines have both power and hand feeds for all three of the movements; others have longitudinal and transverse movements so controlled and the vertical is operated by hand; or the longitudinal movement alone is operated both by power and by hand, and the transverse and

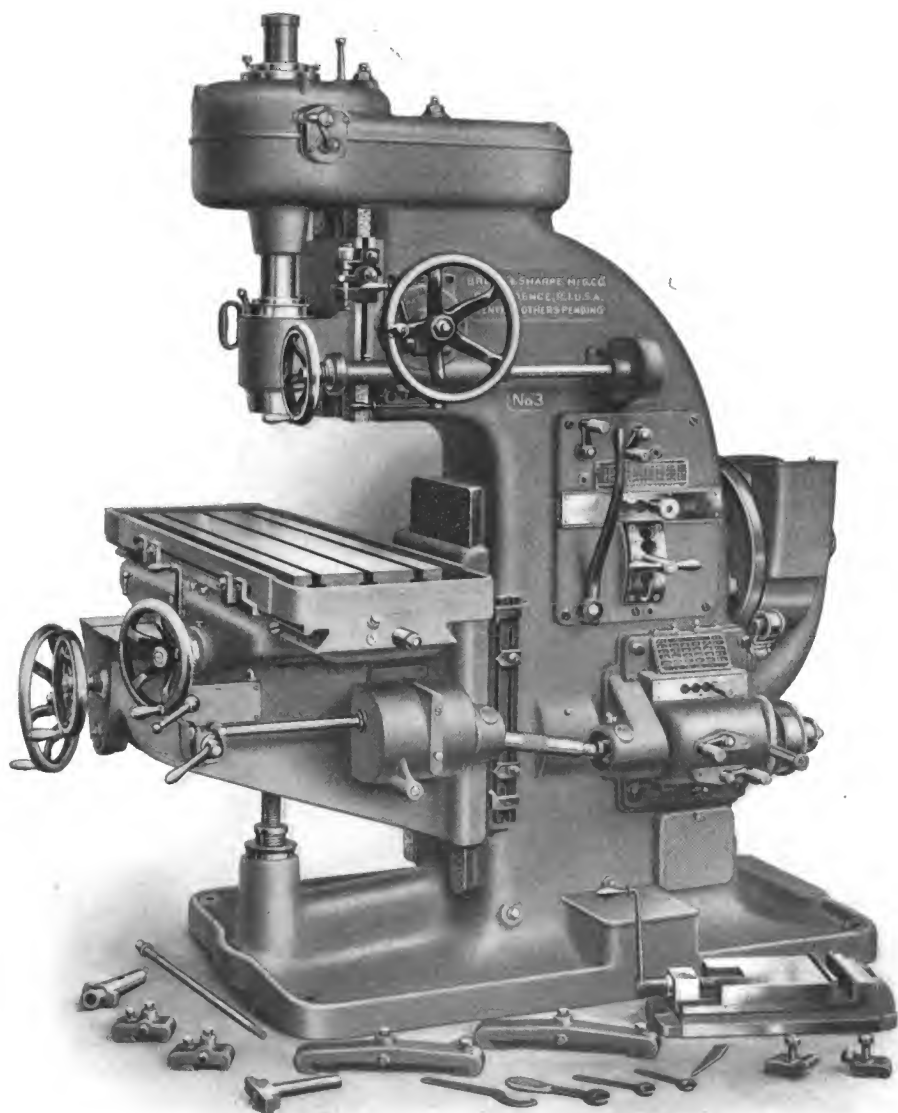
vertical movements are made only by hand. Lead screws are used for operating all of the table movements in many of the smaller sizes and all of the larger machines, but in some of the smaller ones a rack and pinion are employed for the longitudinal movement. The smallest sizes of machines have no power feeds at all, and are called hand milling machines. (See illustration on page 46.) In these, the table and knee are moved by means of racks and pinions operated by levers. They are convenient for manufacturing purposes on some classes of small work, as they can be operated very rapidly.

It is the practice in the classes of work to which the medium and larger sizes of plain milling machines are adapted to take heavy cuts at fast speeds and coarse feeds. The rigid construction of the machine enables this to be successfully done, and it is in this ability that the chief value of the plain machine is found.

Universal Milling Machine. The Universal milling machine is justly regarded by many to be the most important machine tool employed today; for with it much of the work of the planer and shaper—heretofore considered indispensable machines in every shop—can be done with an appreciable saving of time. Spur, bevel and spiral gears, twist drills, and all kinds of straight and taper milling can also be economically produced.

It was first patented February 21st, 1865, by Mr. J. R. Brown, of the firm of J. R. Brown & Sharpe, who designed it for the purpose of milling the grooves in twist drills, but adopted it shortly after for producing small spirals used in the manufacture of sewing machines. (An illustration of the original universal milling machine is shown on page 6.)

The cuts on pages 10 and 44 are representative of modern universal milling machines. This style of machine is essentially the same in construction as the plain milling machine, and the table has the same movements. But, in addition, the table swivels upon the saddle and can be set at an angle to the spindle in a horizontal plane. Also, it is fitted with a mechanism known as a spiral head, for use in spiral milling and indexing to obtain any required spacing on the periphery of work. The introduction of the swivel renders the table a little less stable than that of the plain machine, though in common practice heavy cuts are taken. It is apparent, however, that the offices of the two machines are in a way distinct. A universal machine is the better for general shop purposes, but where continuous heavy milling of straight cuts is to be done the plain machine is preferable.



Vertical Spindle Milling Machine of Constant Speed Drive Type

Vertical Spindle Milling Machine. The vertical spindle milling machine embodies the principles of a drilling machine. The spindle and table are similarly located, and the cutter is mounted at the end of the spindle. The table on the milling machine, however, has a series of movements that are not found on the drilling machine. For such work as face milling, die-sinking, profiling, etc., the vertical spindle machine offers many advantages over the horizontal style. Some work can be fastened directly to the top of the table, eliminating the use of special fixtures necessary for the same kind of work on a horizontal spindle machine. Furthermore, the operator is enabled to see his work at all times during operation and more readily follow any irregularities in outline. This feature is especially valuable in profiling, cutting odd-shaped slots, etc.

Not all vertical spindle machines are of the column and knee type. There are several styles that have no provision for vertical adjustment of the table. Also some vertical spindle machines have two spindles instead of one, but these are more generally known as profiling machines.

But the combination of the vertical spindle and column and knee constructions has given the mechanical world an exceptionally valuable machine tool. With it, all of the advantages of the vertical spindle, together with those of the column and knee, are acquired. A modern example of this style is shown in the cut on the opposite page. A further convenience of this machine is found in the spindle head, which is adjustable vertically, and can be fed by power, thus enabling drilling to be conveniently done. With the adjustable spindle head and column and knee construction, it is apparent that work of a wide range of heights can be accommodated. Another style of vertical spindle machine, where the spindle is driven by a belt, is shown on page 36.

Different Methods of Driving Milling Machines

Milling machines of the column and knee and manufacturing types are either cone driven or gear driven. The latter class is more commonly referred to as the "constant speed drive."

Cone Drive. In cone driven milling machines, the belt runs directly from a stepped or cone pulley on the countershaft to one of like design fastened, either directly to, or mounted on a sleeve on the machine spindle. In one case the spindle is driven directly and only speeds that are obtained by shifting the driving belt on the pulley steps are available; while in the other an additional series of speeds is procured by the employment of back gears. The cut on page 10 is of the

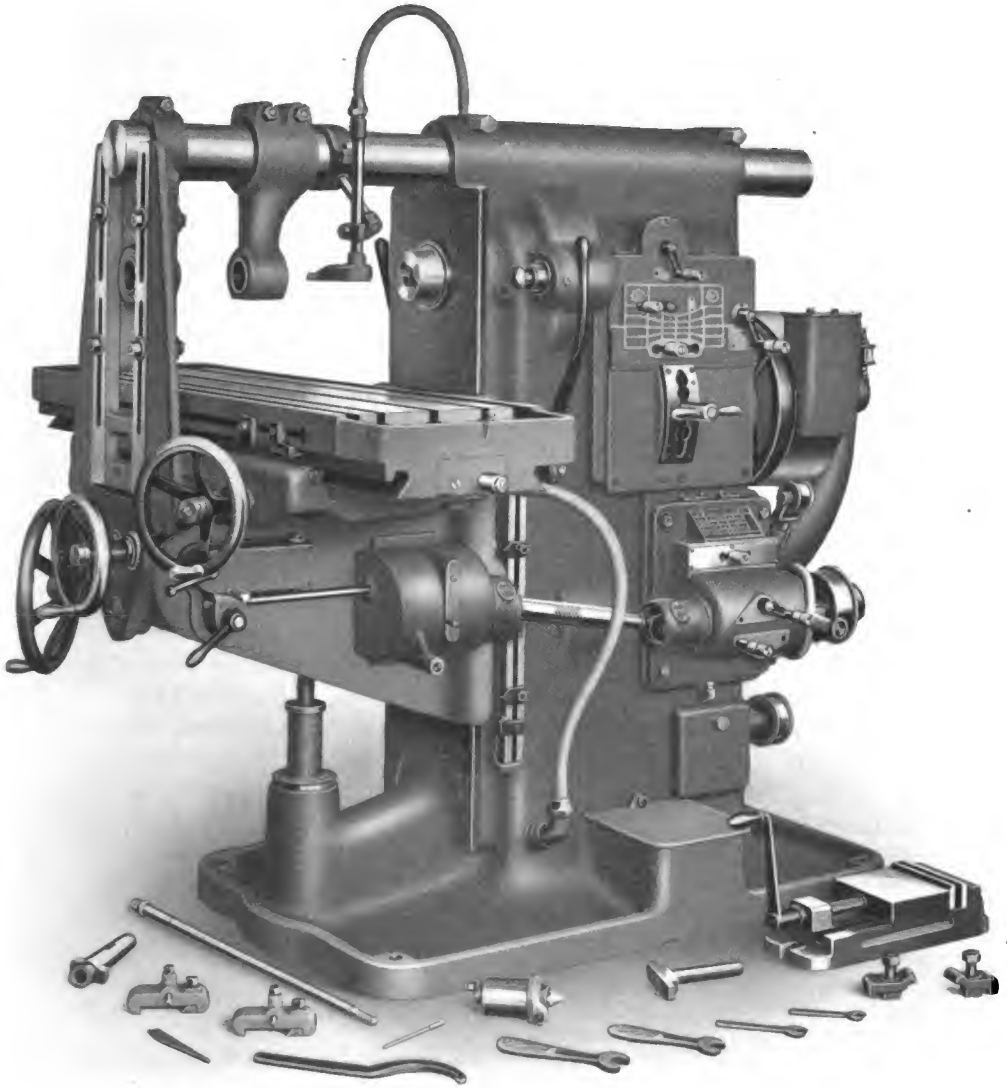
latter type, and the back gears referred to are enclosed at the front of the column, where they are rigidly mounted closely together to overcome torsion and cutter chatter. The feeding mechanism is driven from the rear end of the spindle by a chain and sprockets, and is subject to the speed variations of the spindle.

When the cone method of drive is employed for vertical spindle milling machines, the belt usually leads from the cone pulley on the countershaft to one on a shaft at the back of the machine. Power is transmitted thence to the spindle on the lighter machines, by means of a quarter-turn belt. An application of this method of drive is shown in the illustration on page 36. The heavier machines are fitted with bevel gears, and a vertical shaft from which the spindle is driven by a chain and sprockets.

Constant Speed Drive. The invention of the gear type of drive, or, as it is better known, the "constant speed drive," is, without doubt, the most valuable improvement in design brought out in many years. It is the result of a demand for a machine in which the feeds would be entirely independent of the spindle speeds, and all speeds and feeds would be self-contained, thus doing away with complicated overhead works, or permitting the machine to be driven by a constant speed motor. More power and greater convenience in changing speeds and feeds were also important factors leading to the development of this type of drive.

The introduction of high speed steel marked a new era in cutter manufacturing, and brought about conditions that necessitated machines of higher efficiency. This added impetus to the already growing interest in a machine offering possibilities such as those of the constant speed drive, and, early in 1904, the Brown & Sharpe Mfg. Company placed the first constant speed drive machine upon the market. From the beginning, it was conceded an important improvement, especially for the larger sizes of heavy service machines, where an abundance of power is required, and this has led to its becoming almost universally adopted by milling machine manufacturers. Several examples of constant speed drive machines are shown in this treatise, notably those illustrated on pages 16, 19 and 44.

The general features of this drive are as follows: the belt delivers power to the driving pulley that runs loose on a sleeve on the main shaft of the machine. By means of a friction clutch on the main shaft, operated by levers at each side of the column, power is transmitted from the driving pulley to a train of hardened gears



Heavy Service Plain Milling Machine of Constant Speed Drive Type

leading to the spindle, and in which there are certain change gears operated by levers at the right-hand side of the column. The belt and main driving pulley run at a constant high velocity regardless of the spindle speed, which is entirely dependent upon the ratio of gearing that may be in mesh. The power at the spindle is therefore constant, regardless of its speed.

The mechanism of constant speed drive vertical spindle machines is essentially like that outlined above, except that a pair of bevel gears and vertical shaft are introduced to transmit power to the spindle head, from whence it is communicated to the spindle itself by spur gearing.

The feed changing mechanism is driven from the main shaft by means of a chain and sprockets in all constant speed drive machines. Hence it is completely separated from the spindle drive, in so far as its speeds are concerned, permitting the full range of feeds to be available for every spindle speed. Such an arrangement also permits the table feeds to be rated directly in inches per minute, which is an advantage in that it enables the production of a machine to be ascertained at a glance.

CHAPTER II

Essentials of a Modern Milling Machine

It has been previously stated that the foremost advantages attending the employment of the milling machine are, the production of a great variety of work, and the exact duplication of pieces at an economical cost. In order that these advantages may fully materialize, it is necessary that many requirements be fulfilled in the design and construction of the machine.

These requirements vary to a certain extent with the style and size of machine; taken as a whole, however, they are materially the same. The machines must all be accurate, economical to operate, and durable. Hence, these may be said to constitute the general requirements of a milling machine. Those qualities upon which accuracy is chiefly dependent are thorough workmanship, especially in aligning the working parts, and sufficient rigidity. In order to be economical in operation, a milling machine must have ample ranges of spindle speeds and table feeds, and plenty of power, so as to adapt it to the many varieties of work. Further, its efficiency must be high, and its parts must be conveniently arranged to allow quick manipulation and ready adjustment. The third general requirement, durability, is, to a great extent, dependent upon the design and quality of materials that enter into the construction of a machine. It is also influenced by several of the already-mentioned points that are essential to accuracy and economy. To particularize then, the requirements of a milling machine are thorough workmanship, correct alignment of all working parts, sufficient rigidity, wide ranges of speeds and feeds, ample power, high efficiency, durability, and convenience in design and operation.

Workmanship. It is stated above that the dependence of accuracy upon workmanship in the building of a milling machine is of greatest importance in connection with the alignments of the different working parts. Correct alignments are most essential because they establish exact positions of the various parts with relation to one another. Any error in alignments is transmitted from one part to another until it is finally communicated to the piece of work, where it is liable to be

multiplied. If the work is of the coarser grade, or mere roughing cuts are being taken, a few thousandths of an inch over or under size do not matter; but when finishing a piece that must come within close limits of a pre-determined size, a very small error is often sufficient to seriously impair its quality.

All of the important alignments in milling machines are obtained by scraping, a process consisting of going over the different bearing surfaces by hand with a chisel-like tool, and removing the highest spots until a maximum number of bearing points is secured. Flat bearings are scraped to conform to master surface plates and straight edges, and the boxes of important cylindrical bearings are scraped to fit the revolving piece, which is ground. This work necessarily calls for much skill on the part of the workman, and the care with which scraping is performed largely influences the accuracy of the resultant bearings.

Principal Alignments of Milling Machines. Broadly speaking, the principal alignments of all milling machines are those of the spindle and table. They are, of course, affected by various minor alignments throughout the machine, but it is not essential to take up each of these in detail. The alignments of the table on horizontal spindle column and knee machines should be such that its upward and downward movements will be perpendicular to the spindle axis. Its longitudinal and transverse movements should be in horizontal planes, the longitudinal being parallel to the face of the column on plain machines, and on universal machines when the table is set at zero; and the transverse at right angles to the column.

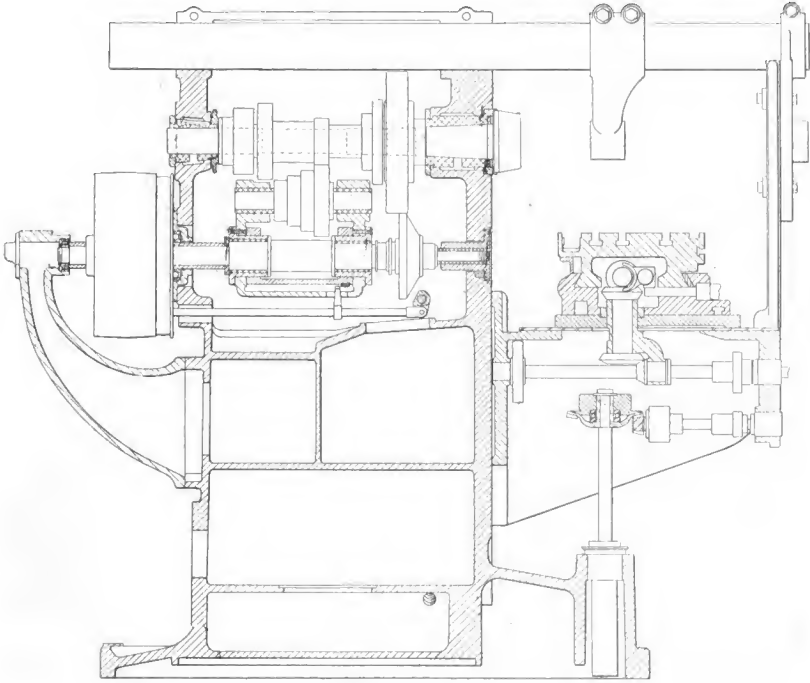
On universal machines, the table should also swivel in a horizontal plane.

These alignments of the table and spindle of column and knee machines are typical, and it is easy to understand from them what the alignments of other types of milling machines should be.

While we have emphasized the importance of good workmanship in scraping bearing surfaces, in order to obtain accurate alignments, it must be understood that certain elements in design are largely responsible as to whether the alignments remain accurate or not. A bearing surface may be scraped ever so carefully, yet the lack of sufficient weight in the casting, or of ample proportions of the bearing surface itself, will quickly result in the alignments becoming inaccurate. Thus it is apparent that if alignments are to be permanent, the proportion of the different parts, including the bearing surfaces themselves,

must be ample to easily support the weight brought upon them. The accuracy of alignments can be ascertained upon first operation of a machine, but their permanency can be determined only after a considerable period of service.

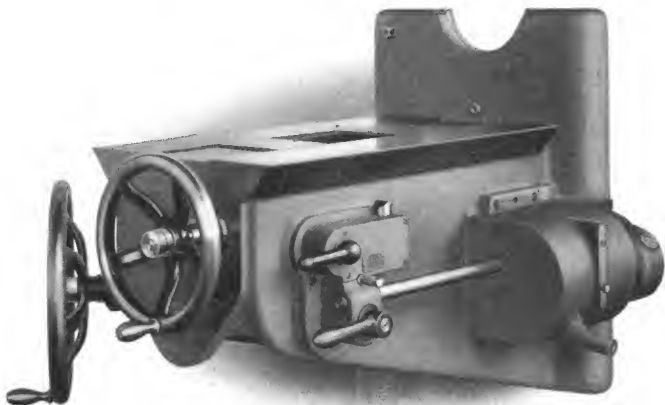
Rigidity. This requirement is of just as great importance to the success of a milling machine as correct alignments. Any machine tool must be rigid in order to produce accurate, well-finished work;



Brown & Sharpe Milling Machine, showing large base, thick walls and internal bracing. The spindle bearings are mounted directly in thick walls of column.

the milling machine must be particularly so. It is not until within the past few years, however, that the real value of this essential has been fully appreciated. This is owing to the fact that up to that time the milling machine had not become so extensively used for manufacturing purposes. In this field it must be capable of not only producing accurate work of high quality, but of producing it rapidly. The more rapidly a machine is operated, the greater is its tendency to vibrate. This is further augmented by the use of cutters

made from high speed steel, for they can be made to take unusually heavy cuts at fast speeds and coarse feeds. It is impossible to eliminate all vibrations from even the very best types of machine construction, but they may be reduced to a minimum, or, in other words, to a point where they will not affect the accuracy of the work, if every part is so constructed that it is capable of resisting heavy stresses, and absorbing vibrations. Weight and well-proportioned construction are most necessary to overcome vibrations.



**Knee of Brown & Sharpe Milling Machine
illustrating the points mentioned opposite**

The essentials in the design and construction of the column and knee machine that serve well to illustrate the general points that conduce to rigidity in all machines, follow:

First, the base must be large and heavy enough to provide a firm foundation, and the walls of the column must be thick and strongly braced, in order to support rigidly the weight of the working parts and withstand the strains of operation. Especially is this true of the front wall, which forms the basis of support for the table. If this is not heavy enough and well braced, it will have a tendency to buckle under the heavy loads it is required to support, which will not only admit of vibrations, but also destroy the alignments of the machine. Another point in connection with this front wall, or vertical slide, is that it should be wide in proportion to the size of the machine, as the wider a flat bearing, the more stable it is.

All shafts should be of large enough diameter to resist bending and torsional stresses, and gears should be of ample size to give

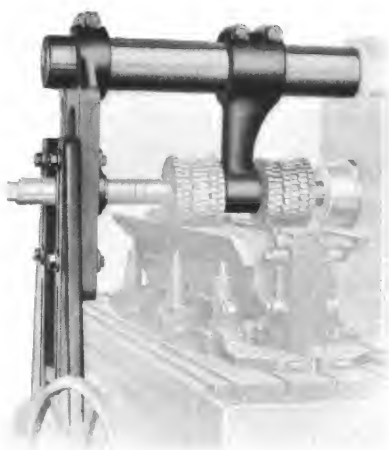
strength and good wearing qualities, and to transmit the requisite power to the spindle. Cylindrical bearings should be firmly supported, and the boxes should be as long as is consistent with a high degree of efficiency. Those of the spindle are most stable when mounted directly in the thick walls of the frame.

A heavy, well-braced construction is necessary in the knee in order to overcome all tendency to vibrate or sag under the load of the saddle and table during operation. It is also well, to have the back of the knee that fits the vertical column extended above the top as this gives a larger bearing surface to resist sagging tendencies and vibrations under heavy loads.

It has been found from experimenting that vibrations arising



during operation are usually manifested first in the table, and are transmitted from there to other parts. One reason for this is the several joints between the table and column. It is impossible to eliminate all lost motion between the bearing surfaces, and still have the parts free to perform their different functions. But weight has much to do with the stability of the table, and in many cases vibrations have been practically overcome by simply adding more weight to this part. It is important, therefore, that both the table and saddle be of sufficiently heavy construction. Transverse braces, however, placed at frequent intervals on the under side of the table often produce the required rigidity without adding unduly to the weight. Efficient clamps on the flat bearings of the knee, saddle and table, also provide means of rigidly fastening any one or two of the table movements that may not be in use, thus eliminating vibrations.

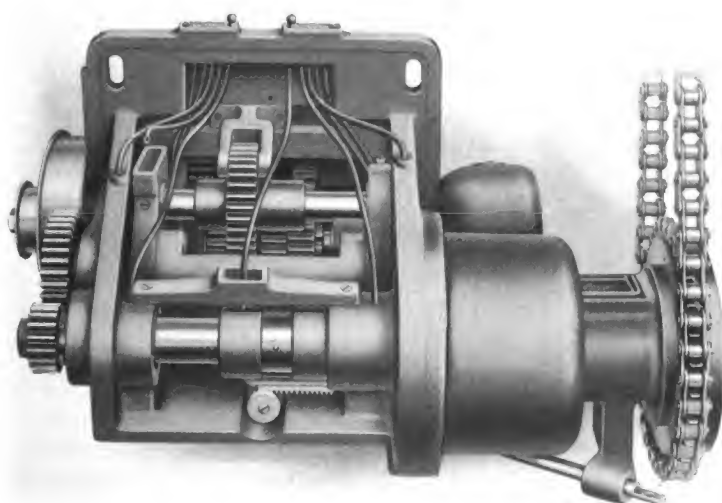
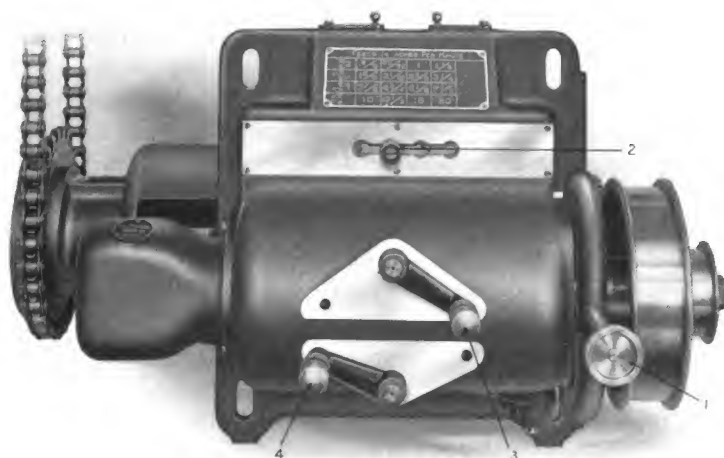


**Showing Firm Support of Arbor
on Heavy Job**

Another point that influences largely the rigidity of the table is the size of the flat bearing surfaces in the saddle and on the knee. It is essential that the table bearing in the saddle be wide and sufficiently long to prevent too great an overhang when the table is at the ends of its traverse, and the top of the knee be of ample width to easily support the weight placed upon the table.

Other features which conduce to rigidity are: a large overhanging arm with a support for the outer end of the cutter arbor, and an intermediate bearing on the larger machines, also arm braces that firmly tie the overhanging arm and knee together.

Speeds and Feeds. It is rare that the conditions surrounding any two jobs on a milling machine are the same. Sometimes the work is of the heaviest class to which the machine is adapted, requiring gangs of cutters operating at a comparatively fast speed and coarse feed; again it is of a lighter type, requiring only one cutter operating at a fast speed and fine feed. The shape of the piece sometimes demands that the cutter be fed through faster or slower than would ordinarily be done in milling a plain surface. Different materials cannot be milled at the same speeds and feeds. Cutters of large diameter are employed for some jobs, and to get the proper peripheral speed, they must be rotated at a slower rate than those of smaller diameter. A finishing cut with the same cutter is usually taken at a faster speed, and correspondingly lower rate of feed per revolution of spindle than the roughing cut, in order to obtain a smoother finish. All these, and many other conditions, make it necessary that a machine have a wide range of spindle speeds and table feeds. Furthermore, there must be many intermediate speeds and feeds between the highest and lowest in the ranges. In many cases it is also advantageous to have the speeds and feeds independent of one another, so that the spindle speed may be changed without disturbing the rate of table travel. This is possible in the constant speed driven machine,



**Feed Changing Mechanism on Brown & Sharpe
Milling Machine**

and constitutes a particular point wherein this type of drive differs from that known as the cone drive.

The cone drive machine is admirably adapted to all classes of work where it is not necessary to use combinations of extreme speeds and feeds. In these cases, however, it cannot fulfill the requirements. For instance, it is impossible to obtain a coarse enough feed for a cutter of very large diameter, because the feeding mechanism is invariably driven from the end of the spindle, and is subject to the speed variations of this part. Consequently, when a large cutter is being used, the spindle is usually driven at its slowest speed, and the fastest feed that is then available is not coarse enough. Likewise, a correct combination of speed and feed cannot be had for a small mill, as this should run at the fastest spindle speed, and, when it does, the finest feed obtainable is much too coarse. The majority of work, however, does not require such combinations, and when medium-sized mills are used and work of ordinary classes is done, the cone drive machine is very satisfactory.

Owing to the dependence of the feeds upon the spindle speeds in the cone drive machines, it is necessary to rate them as so much per revolution of the spindle. This requires that the feed being used be multiplied by the spindle speed, in order to obtain the rate of production in inches per minute—the most generally accepted standard.

With the constant speed type of drive any combination of spindle speed and table feed within the ranges of the machine can be obtained, and thus the large, medium, or small sizes of cutters can all be run at the most practical speeds and feeds. This is due to the fact that the spindle and feeding mechanisms are driven independently of each other from the same main shaft, which revolves at a constant velocity at all times. Feeds obtained in this manner can be rated directly in inches per minute, a point that in itself constitutes an important advantage.

On practically all of the Brown & Sharpe constant speed drive machines, sixteen changes of spindle speed, and at least sixteen different feeds are available, while some sizes have as many as twenty feeds. Their range varies slightly in the different sizes of machines, but is such in every case that the correct combination can be had for any cutter that is used.

Power. A milling machine must have ample power, or its use is exceedingly limited. This applies to all styles and sizes of machines,

but more particularly to the larger ones that are used in commercial manufacturing, where an economical production means the taking of heavy cuts at fast speeds and coarse feeds.

In driving machine tools, the power delivered to a machine depends upon the diameters of the driving pulleys, and size and velocity of the belt. A wide belt running at a high velocity on pulleys of large and equal diameters develops the maximum power, and, as its speed and width are lessened, its pulling ability decreases correspondingly. Likewise, it transmits less power, as the pulley on the machine exceeds in diameter the pulley on the driving shaft, for, when the surface contact on the driver becomes smaller, the belt has a tendency to slip.

Hence, in the factor of power is found another important difference between the cone and constant speed drive machines, with the advantage in favor of the latter.

The cone drive machine is very suitable for light and medium work, of such as the majority of milling consists, but when it comes to driving a large cutter through a heavy cut at a slow spindle speed and coarse feed, the requisite amount of power is lacking. This is due to the belt being upon the smallest step of the driving pulley, where it runs at its slowest velocity, and has a small arc and surface of contact.

On constant speed drive machines, the pulley is of the same, or almost equal diameter to that on the overhead shaft, and runs at a constant high velocity, irrespective of the spindle speed. Furthermore, a wider belt can be employed than on cone drive machines. As a result, a maximum amount of power is delivered to the machine pulley, and is transmitted through heavy gearing to the spindle, under all conditions, thus fitting this style of machine particularly well to the heavier classes of work. Another advantage of this drive is its particular adaptation to the application of a motor. The constant speed type of motor, which is more economical, both in first cost and in the amount of power consumed, than the variable speed motor, can be employed. This is also the most simple and compact form of motor drive. When applied to Brown & Sharpe Machines, the motor is mounted on a bracket at the back of the column, where it is away from dust and chips of the table (see page 176). Furthermore, by placing it in this position the floor space occupied by the machine is not increased, as it is necessary to leave room behind the machine to allow the overhanging arm to be pushed back when not in use.

Efficiency. Production costs are of vital importance to the shop owner, and no one factor influences them to a much greater extent than the efficiency of the different machines employed. Where this is low, the amount of power consumed for which there is no apparent return is higher than it should be, with the result that the cost of production is increased. It is essential, therefore, that a high degree of efficiency be attained in the milling machine, so that a maximum amount of work may be produced for the power consumed.

In order to obtain the highest degree of efficiency in milling machine construction, it is necessary that the utmost care be taken in designing the different parts, selecting materials, and in the quality of workmanship in building.

All parts must be proportioned in accordance with the functions they perform. They should be heavy enough to resist any stress that would tend to cramp operating movements. For instance, cylindrical shafts should be large enough in diameter to eliminate bending tendency, for this will cramp them in the bearings, thus interfering with their free revolution. Care must be taken, however, that the different parts are not proportioned so heavy that they will be cumbersome and thus produce excessive friction, which is detrimental to efficiency. It is here that the selection of materials is of value, for often the weight of a part can be made lighter by the use of a material of greater strength.



**Pointed Teeth of
Hardened
Change Gear**

The size of bearing surfaces is of especial importance to efficiency, as well as to permanent alignment and rigidity. It is between them that friction arises in operation, and in order to reduce this to a minimum, their proportions should be such that the parts may move freely under the heaviest load.

Correct alignments of bearing surfaces are as essential to efficiency as to accuracy, in order that the working parts may move freely. Any error in alignments tends to cramp or wedge the moving parts.

Simplicity of parts and the use of spur gearing as far as possible are also elements that contribute largely to high efficiency.

Durability. The first cost of a milling machine, like any other modern machine tool, is comparatively great, and to make its employment economical, this cost must be spread over a long period of service—in other words, the machine must be durable. Strong design and the use of high quality materials throughout the machine are most essential to durability.

Thorough workmanship is also an important factor. Seemingly small details in construction should receive careful attention, for it is these that many times give rise to serious trouble. The fitting of different parts, and making of all alignments should be carefully done, and means should be provided for taking up wear at any points where it is apt to occur. In connection with the wearing qualities of different parts, the selection of materials is an important factor; parts that are subject to continuous usage, such as the change gears in constant speed drive machines, should be made of a hard material having good wearing qualities. In Brown & Sharpe machines, these gears are made of steel and are hardened.

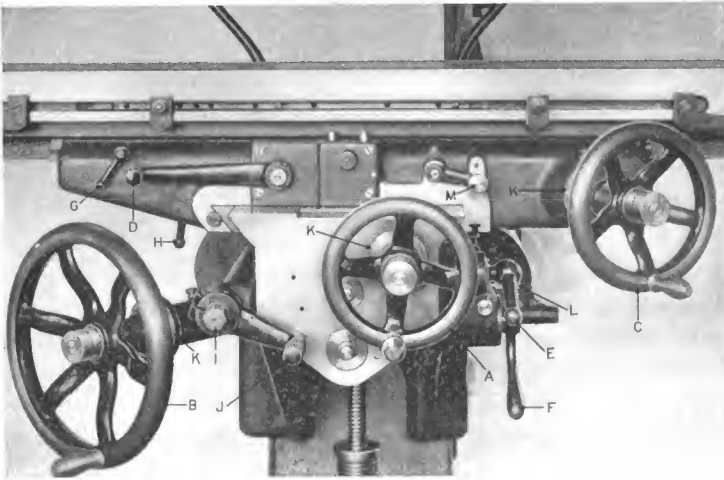
Where change gears are being thrown into and out of mesh frequently by a tumbler arrangement, it is well to have the tops of the teeth pointed, and the ends of teeth in sliding gears chamfered. These features not only facilitate throwing the gears into mesh, but also reduce the danger of teeth becoming bruised or broken, which is apt to happen when gears with teeth of the ordinary shape are thrown into mesh.

Rigidity is as essential to durability as to accuracy, since the existence of vibrations causes very rapid wearing of parts. Hence, every part should be of stable enough construction to resist vibrations under all practical working conditions.

Beyond these points, and that of provision for lubricating all bearing surfaces, the matter of durability is more especially a question of the care devoted to the machine while in use. Its failure to be durable because of lack of proper care cannot be attributed to any faults in design or construction. The information given in the next chapter on the care of milling machines is very important to those who have charge of these machines.

Convenience. Much time is lost in operating a milling machine that is inconvenient in any way for the workman to handle: therefore, from the standpoints of economy and efficiency, convenience is a most desirable quality. To be convenient, a machine must be so designed

**All Hand-Wheels, Operating Levers, etc., Located
Where Workman Can Reach Them Handily**



- A, Transverse hand feed.
- B, Vertical hand feed.
- C, Longitudinal fine hand feed.
- D, Longitudinal automatic feed trip and reverse lever.
- E, Transverse automatic feed trip lever.
- F, Vertical automatic feed trip lever.
- G, Longitudinal movement clamp.
- H, Transverse movement clamp.

- I, Vertical movement clamp.
- J, Feed reverse lever (all feeds). At right of knee on small machines.
- K, Adjustable dials graduated to thousandths of an inch.
- L, Transverse and Vertical feed locking lever.
- M, Lever to disconnect table feed screw when using circular milling attachment.

and constructed that work and tools can be readily placed in position and removed from the table, spindle and table feed adjustments easily made, and all working parts readily accessible.

As the station of the operator is at the front of the machine, all controlling levers and hand-wheels for stopping and starting the machine and the different table movements should be within reach from this point.

The spindle speed and table feed changing levers of constant speed driven machines are placed on the left-hand side of the column by some builders, and on the right by others. This is more a matter of choice than anything else, the chief advantage being in having them conveniently grouped and so designed that the manner of operation is clear.

Arrangements for lubricating the various parts and making adjustments to compensate for wear should be such that these can be accomplished with a minimum loss of time.

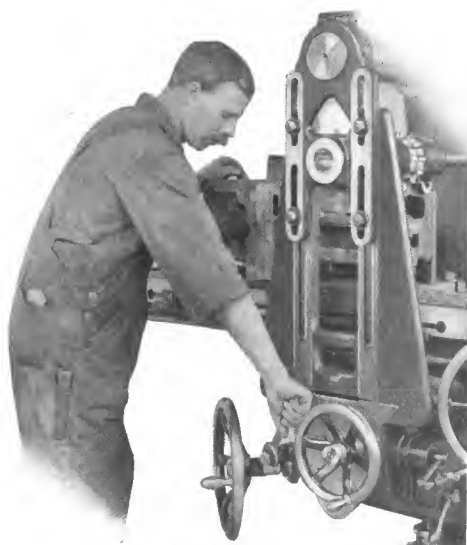
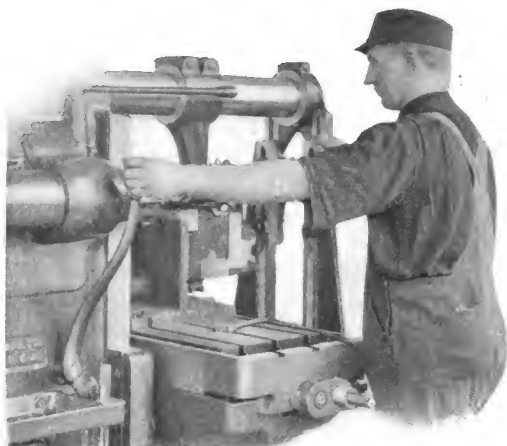
Hand or Automatic Feed. It is essential that the table of all milling machines used for manufacturing purposes, with the exception of the very smallest of the plain type, be fitted with both hand and automatic feeds. In the case of this exception, the work done is of such a small character that the machine can be operated more rapidly by hand than it could be if an automatic feed were applied. By the use of automatic feeds, one operator is enabled to run several machines on the majority of commercial work.

Tool room machines, and those used for miscellaneous milling, should be fitted with both hand and automatic feeds, for, while much of the work requires careful feeding by hand, there are, nevertheless, many times when an automatic feed can be employed and the mechanic can devote his attention to some other detail of the job while a cut is being taken.

Power Fast Table Travel. On large machines it is necessary that the table be provided with a power fast travel in order that the minimum amount of time will be consumed in moving the work to and from the cutter.

Also a faster rate of travel is thereby provided than is possible by hand, and the operator is relieved of the laborious task of moving the heavy table and work many times a day. Both of these are points which materially influence increased production.

There are Friction Clutch Levers at Both Sides of Machine for Convenience of Operator

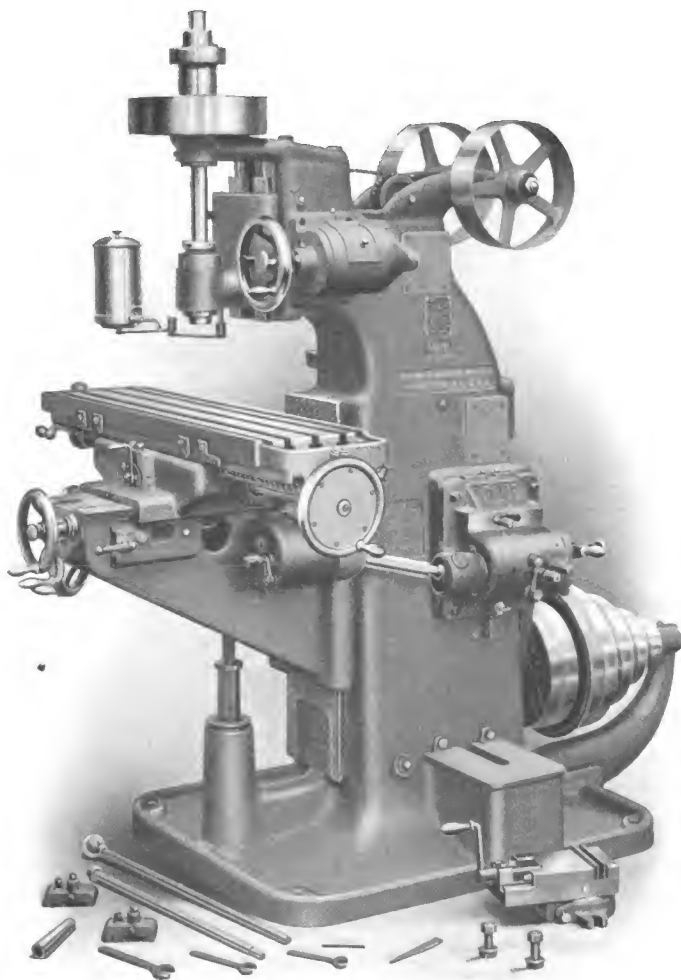


Operator Does Not Have to Go Around Table to Clamp Knee

Oil Can or Pump and Tank. Every milling machine must be fitted with some arrangement for lubricating the cutters when working on steel, or wrought iron. Either an oil can or a pump and tank are employed for this purpose. For machines that are used for light work and miscellaneous milling, an oil can is found satisfactory, as the amount of lubricant used is small and a pump and tank complicate the machine and make more for the operator to care for. When heavy and manufacturing milling is being done, however, and an abundance of oil is required, both to cool the cutters and wash out chips, it is not always practical to supply it through the medium of a can, as this cannot be made large enough to hold sufficient lubricant to last long. By fitting the machine with a pump and a tank to which the used oil returns by gravity, a copious supply is available at all times. When it is not needed it can be shut off and a relief valve in the piping returns the unused oil to the tank.



**No Exertion to Run the Table Back or
Run it Up to Cut**



**Vertical Spindle Milling Machine
with Spindle Driven by Belt**

CHAPTER III

Erection and Care of Machine

Erection. A machine should be placed upon a level, and, if possible, a solid floor or foundation. If the foundation is not firm, undue vibrations will exist and possibly impair its accuracy and durability. Either stone or concrete makes an excellent foundation for the larger sizes. Neither of these can be used, however, when it is desired to place a machine above the ground floor of a building, and it is best, in this case, to locate it directly over a beam; not in the middle of a bay.

Ordinary wooden shingles are commonly used in leveling a machine. When the exact position has been determined, the fastening screws or bolts should be screwed down until nearly tight. A spirit level should then be used to test the top of the table, both longitudinally and transversely. If the machine is too low at any corner, drive a shingle under the base at this point to bring it up. When the table is found to be level in every direction, the nuts, or bolts, should be brought up solidly. It is well, even after tightening the bolts, to test the surface of the table once more, as this tightening sometimes throws the machine out of level again.

Counter-shaft. Putting up the counter-shaft, when one is employed, is usually the first operation in installing a machine. It is generally placed directly over cone drive machines because of the interference of the driving belt with the upper part of the frame if it is located very far at either side. With constant speed drive machines, it is not necessary to place the counter-shaft directly overhead. It may be placed diagonally as long as the belt does not interfere with the overhanging arm when it is pushed back.

The counter-shaft should be level and accurately aligned parallel with the main, or driving, shaft. Where the beams are not uniform enough to bring the stringers to which the counter-shaft hangers are attached level, it will be necessary to shim between the feet of the hangers and the stringers to make the shaft level. The holes in the feet of the hangers are usually in the form of slots, which allow the hangers to be slightly adjusted when aligning the counter-shaft with

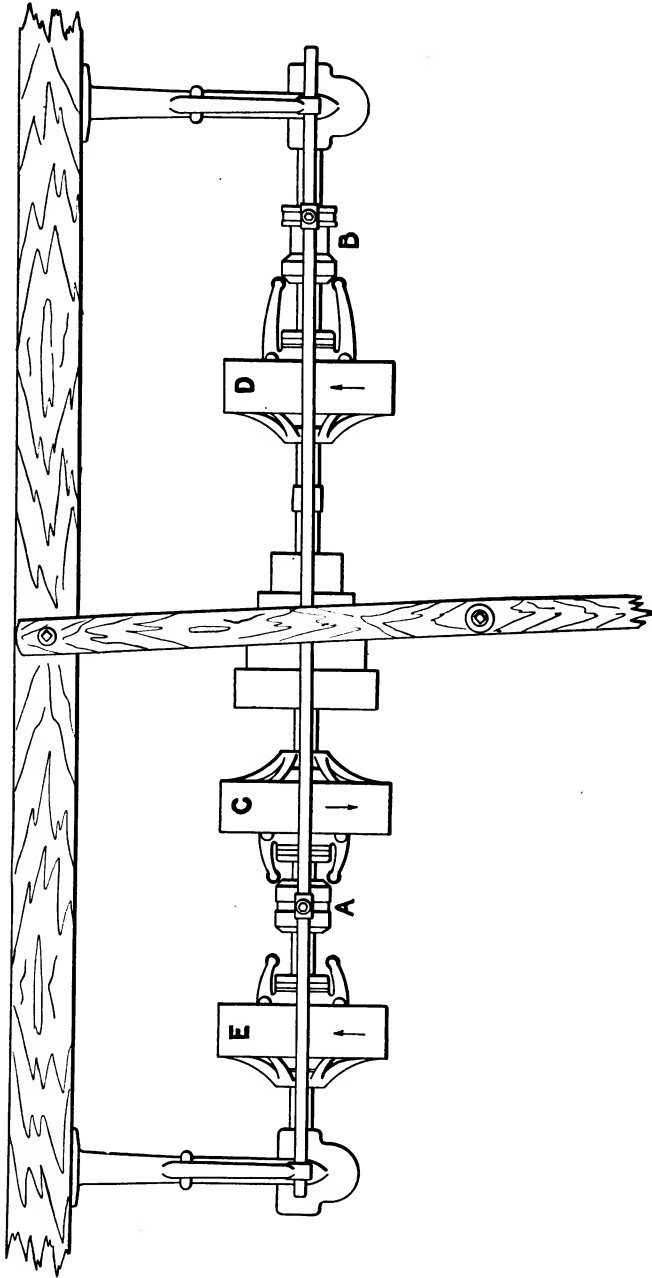


Fig. 1

the driving shaft. In leveling and aligning the counter-shaft, it is the practice to insert the bare shaft in its boxes and take measurements from it. It is afterward removed, the pulleys put on and then replaced in its bearings. When the hangers are securely tightened, the shaft should revolve freely. About an eighth of an inch end play is desirable on a counter-shaft. This can be obtained when placing the hangers.

The shipper handles are most convenient when they come within easy reach from the left front side of the machine, as this is the position commonly taken by the workman to watch the operation.

Counter-shaft bearings are lubricated in various ways. In our particular type the oil is raised from reservoirs in each hanger by means of rope wicks as shown in Fig. 2.

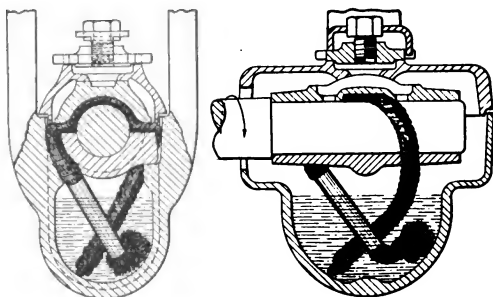


Fig. 2

As a rule it is not necessary to draw off and replace the oil in counter-shaft reservoirs at very frequent intervals if a good machinery oil is used. If the reservoirs are thoroughly cleaned and filled with fresh oil once every year or so they rarely need much attention. It is good practice, however, to put in a little oil every three or four months in order to insure maintaining the proper level.

The arrangement of a three-friction pulley counter-shaft is shown in Fig. 1. Its operation is as follows: A movement of the shipper to the right from the position in which it is shown, causes thimble A to spread the friction levers or engage pulley C. Throwing the shipper to the left until thimble A is about central between pulleys C and E, causes thimble B to spread the friction levers or engage pulley D. A further movement of the shipper to the left allows the levers of pulley D to slip over onto the smaller diameter of thimble B, disengaging the clutch of this pulley; at the same time thimble A spreads the levers engaging pulley E.

Diameter of Pulley on Driving Shaft. To find the diameter of pulley required on the driving shaft for driving the counter-shaft at a given speed, multiply the required speed of the counter-shaft in revolutions per minute by the diameter in inches of the pulley on same, and divide the product by the revolutions per minute

of driving shaft. If, for instance, the speed of the main shaft in a shop is 200 R. P. M., and it is required to drive a counter-shaft, having a pulley 14 inches in diameter, 320 R. P. M., the diameter of the main shaft pulley is found as follows:

$$\frac{320 \text{ R. P. M.} \times 14''}{200 \text{ R. P. M.}} = 22.4'', \text{ diameter of pulley required on main shaft.}$$

When the counter-shaft has two or more pulleys whose speeds differ, a separate calculation is required for each. And when no counter-shaft is used, the calculation is the same as above, except that the required speed and diameter of the machine pulley are substituted for the diameter and speed of the counter-shaft pulley.

Importance of Keeping Machine Clean and Well Oiled. Many workmen fail to appreciate the importance of keeping a machine clean and well oiled, and we cannot emphasize this point too strongly. Proper attention to these details influences the accuracy and efficiency of a milling machine and prolongs its life, while neglect to attend to these matters has ruined many a good machine.

Working parts most exposed to dust, dirt or chips, should be frequently cleaned and oiled. Chips should not be allowed to collect upon the surface of the table until they fall over the sides on to the flat bearings on the top of the knee. Care should also be taken to prevent chips and dirt getting between the knee and column, causing scoring of these flat bearings and throwing the knee out of alignment.

Oil tubes and channels many times become clogged with a gummy substance, due to the accumulation of dirt in the oil, and also to decomposition of the lubricant itself. This can be effectively removed without injury to the bearing surfaces by flushing the tubes and channels with gasoline or naphtha. It is well to do this occasionally to insure free passage of oil to the bearings, for if the bearing surfaces, especially cylindrical ones, run dry, they become roughed up, which necessitates taking them apart, and entails considerable work before they can be made to run satisfactorily again.

A machine that has been in active service for a period of a year or two, should be thoroughly cleaned and inspected. To do this, requires that it be taken apart to some extent, as it is impossible to ascertain the condition of some of the more important bearing surfaces in any other way. Also it is the only way in which one can make sure that some of the oil channels that are not easily accessible are not filled up.

Only good mechanics who thoroughly understand the construction of the different parts should be permitted to take apart and reassemble a machine, owing to the liability of parts being put together wrongly and alignments imperfectly made, if the work is intrusted to less responsible persons.

Arbors and collars should be kept clean and care exercised that chips do not get into the hole in the spindle or between collars.

Neatness about a machine is usually the mark of a good workman. By assigning definite places to tools and attachments and returning them immediately after using, he is able to know just where to look for any one whenever he wants it. The time required to replace tools in this way is more than offset by the advantage of being able to readily find them again; besides, the tidiness of a machine materially adds to the appearance of a shop.

It is well to remember when applying oil that ordinary bearings can hold only a few drops at a time and that this amount applied at regular and frequent intervals is far more beneficial than a flood of lubricant at irregular periods. It is a good practice to have one man attend to the oiling daily in shops where the machines are used by different workmen.

Kind of Oil. There are so many good machinery oils upon the market that it is hard to specify any one as the best to use for lubricating a milling machine. Any good coal or mineral oil can be used. Never use an animal oil, as it will gum up the bearing surfaces, oil channels and tubes, and have a tendency to retard rather than render easy the movements of the different parts. It might also be said that in buying machinery oil it is always safest to purchase a lubricant of reliable quality instead of experimenting with the less expensive brands. It is cheaper to buy good oil than to run the risk of damage to bearings from overheating or scoring.

Care of Driving Chain on Motor Driven Machines. The care of the driving chain on motor driven machines is important. It should be kept clean, well lubricated and adjusted. To clean a driving chain, remove it and immerse in a bath of kerosene or gasoline. This will loosen up the gum and dirt, and by working the joints while in the bath, foreign matter will come out. Remove the kerosene or gasoline by soaking the chain in a very hot and fairly strong solution of soda and water. Wipe dry and immerse in a bath of warm and quite thick lubricating oil for several hours. This treatment should be applied about every two or three months.

A good quality of lubricant that is free from tendency to gum should be used, and a generous quantity applied daily.

The tension of the chain is usually regulated by the adjusting screws in motor bracket. It should run at a tension that might be termed just a little too slack for a leather belt; that is, a slightly greater sag should be allowed.

Adjustments. As bearing surfaces and parts wear, it becomes necessary from time to time to make adjustments, and at all important points convenient means are provided for doing this. Flat bearings are provided with tapered gibs that are easily adjusted, and cylindrical bearings, like those of the spindle, have ready means of taking up wear. It is essential that any adjustment required be promptly

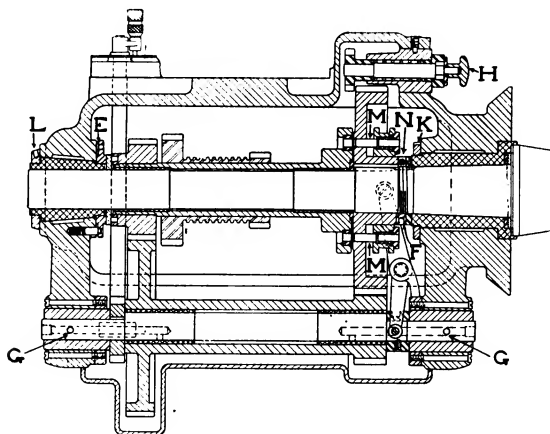


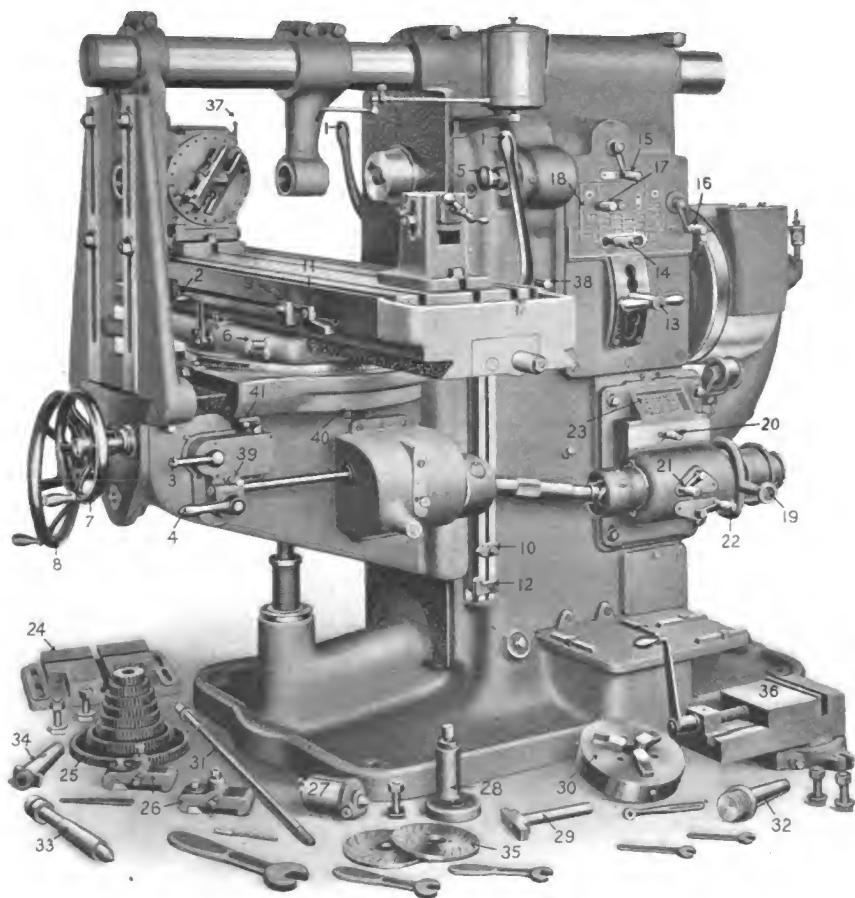
Fig. 3

made, for otherwise the accuracy of the machine is impaired. Furthermore, parts wear much more rapidly as the lost motion becomes greater. By a little examination and adjustment every now and then, the efficiency of a machine can be maintained and its life indefinitely prolonged.

Before proceeding to adjust or take anything apart, it is a good plan to carefully study its principle of construction. Many times this simple precaution will obviate considerable trouble.

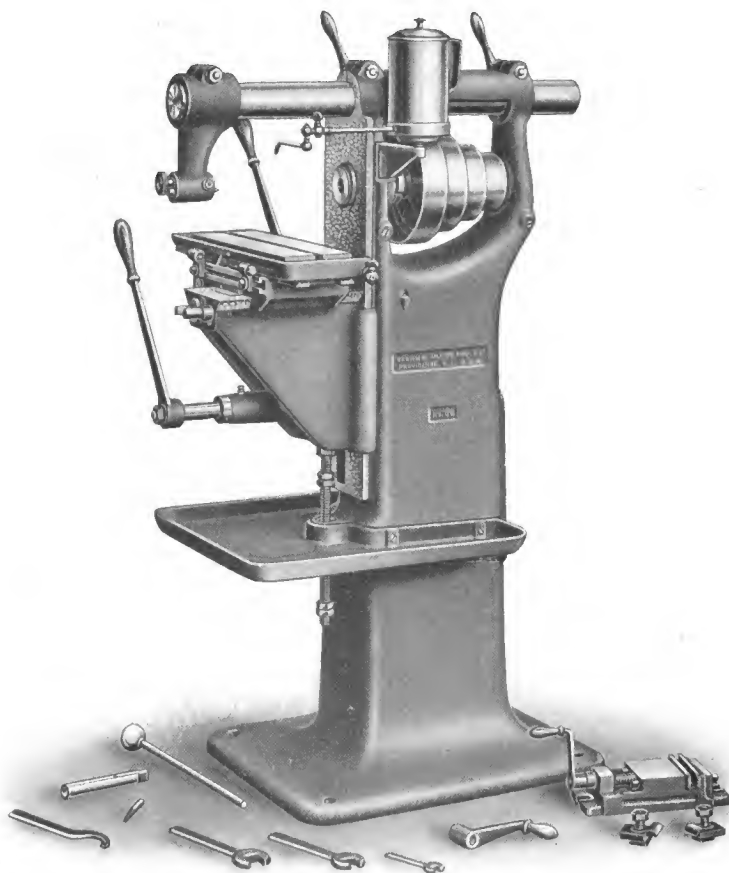
The prevailing practice in designing spindle bearings is to have the front bearing on the spindle tapered and the rear bearing straight. On our machines the front bearing is adjusted by loosening check screw N and tightening nut F, Fig. 3. This draws the spindle back into the box, and as the bearing is tapered, the lost motion is taken up.

Should it become necessary, after running a machine for a number of years, to obtain more adjustment in this front box, the spindle can be removed and the washers between the spindle collar and the front of the box can be reduced a little in thickness. The adjusting nut F will then take care of the wear for another long period. Nut K should not be disturbed, as this merely holds the box in place. The rear box is split and fits in a taper hole in the frame. It is adjusted by loosening nut L and tightening nut E.



Explanation of Levers, Hand-wheels, etc., on Brown & Sharpe Constant Speed Drive Milling Machines

1. Friction clutch levers for starting and stopping machine.
2. Power feed trip and reverse lever for longitudinal movement of table.
3. Power feed trip lever for transverse movement of saddle.
4. Power feed trip lever for vertical movement of knee.
5. Knob for fine adjustment of spindle.
6. Table feed disconnecting lever.
7. Hand-wheel for transverse movement of table.
8. Hand-wheel for vertical movement of table.
9. Adjustable dog for controlling length of table movement.
10. Adjustable dog for controlling length of knee traverse.
11. Safety dog for preventing table running too far.
12. Safety dog for preventing knee running too far down.
13. Spindle drive tumbler gear lever.
14. Knob for sliding the tumbler gear.
15. Quill gear adjusting lever.
16. Back gear adjusting lever.
17. Spindle reverse lever.
18. Index plate of spindle speeds.
19. Feed drive tumbler gear lever.
20. Knob for sliding the tumbler gear.
- 21 and 22. Levers for moving change gears.
23. Index plate of table feeds.
24. Raising block for spiral head.
25. Change gears for spiral head.
26. Table stops for preventing longitudinal table movement.
27. Adjustable centre.
28. Centre Rest.
29. Cutter Driver.
30. Chuck.
31. Drawing-in bolt.
32. Chuck collet.
33. Differential indexing centre.
34. Collet.
35. Index plates.
36. Vise.
37. Rapid index pin lever.
38. Fine feed lever.
39. Transverse and vertical feed locking lever.
40. Safety stop for transverse feed.
41. Adjustable dog for transverse feed.

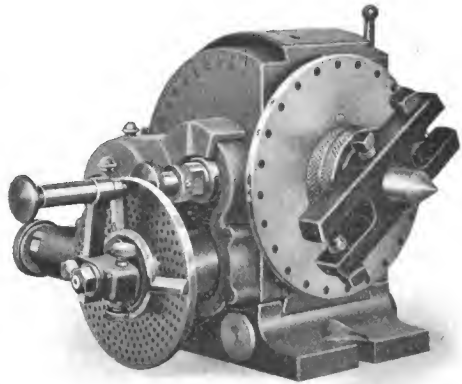


Hand Milling Machine

CHAPTER IV

Spiral Head—Indexing and Cutting Spirals

The mechanism known as the spiral head constituted one of the fundamental parts of the original universal milling machine. Its primary purpose was that of indexing and rotating work in conjunction with the movement of the table for cutting flutes in twist drills. The great possibilities it offered in cutting a large range of spirals, and for doing many other jobs, were soon recognized and developed, until it is now used for an endless variety of operations. With it, ordinary indexing to obtain even spacing on the periphery of pieces, as in cutting teeth in cutters, ratchets, clutch gears, gear wheels and flutes in reamers, taps, drills, etc., can be quickly accomplished. Spiral forms of all common leads can be accurately reproduced by its use.

**Spiral Head**

The spiral head and foot-stock are furnished as a part of all universal milling machines and can be applied, with few exceptions, to plain and vertical spindle machines. Used in connection with a vertical spindle milling attachment, on a plain machine, much the same variety of work can be done as on the universal machine.

In construction, spiral heads of today embody the same principles as the one on the original universal milling machine, but improvements have made them more solid and convenient to operate. Likewise, improvements have been made in the design and construction of the foot-stock.

Since our spiral head is typical of these mechanisms, a description of its various points may aid in understanding the methods of indexing and cutting spirals. The head itself consists of a hollow, semi-circular

casting in which is mounted a spindle that is connected to an index crank through a worm and wheel. Fig. 4 shows the construction of this part. The head casting has dove-tailed bearings at each side that fit the contour of a base plate, which can be clamped to the surface of the table. The alignment of the head with the table longitudinally is provided by means of a tongue on the under side of the base plate that fits a T slot in the table.

The spiral head spindle passes through the head, and is held in place by means of a nut at the small end. The front end is threaded and has a taper hole corresponding to that of the machine spindle.

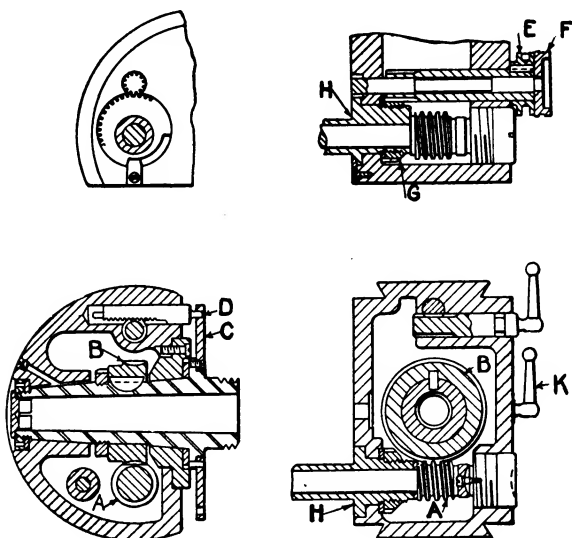


Fig. 4

It is rotated by means of the worm wheel B, which is driven by the hardened worm A that is located on the shaft to which the index crank is fastened. In order to insure accuracy the worm threads are ground after hardening. Through gearing, the index plate and worm A can be driven together from the table feed screw when the index pin is in position in any hole of a plate. When worm A is turned by means of the index crank, indexing may be accomplished, and when it is geared to the table feed screw, spiral milling, in addition to indexing, is made possible. The cutting of the spiral is due to the turning of the table feed screw, which through the interposition of change gears between this screw and the gears that drive the shaft carrying worm A, causes the spindle of the spiral head to rotate as

the table advances, so that the cutter produces a spiral cut in the work. For rapid indexing, when cutting flutes in taps, reamers, etc., the worm A, is disengaged and the spindle turned by hand, the divisions being made by means of the index plate C, which is fastened to the nose of the spindle, and may be locked by the pin D.

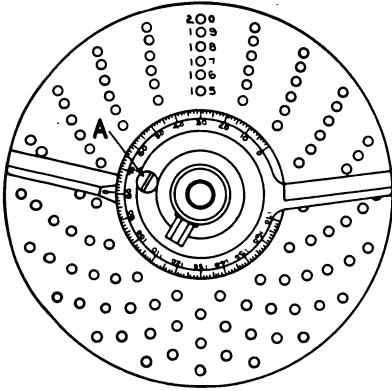


Fig. 5

Graduations on the front edge of the head indicate the angle of elevation to half degrees.

The design of the head is such that it permits unusually long and wide bearings. Furthermore, it sets very low and can be so firmly clamped to the base that the whole mechanism practically becomes one solid casting. Hence, it provides a particularly rigid support for the work, which is a factor of much importance in the class of work that is done upon this mechanism.

Index Plates and Change Gears. Three index plates are furnished with the spiral head, and contain circles with the following numbers of holes:—

Plate 1—15, 16, 17, 18, 19, 20.

Plate 2—21, 23, 27, 29, 31, 33.

Plate 3—37, 39, 41, 43, 47, 49.

The change gears that are furnished have the following numbers of teeth: 24 (2 gears), 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100.

Graduated Index Sector. Without the graduated index sector, much care must be exercised in counting the holes in an index plate when indexing to obtain any given number of divisions. Such a sector enables the correct number of holes to be obtained at each indexing with little chance for error. It is shown in Fig. 5 and

consists of two arms which may be spread apart when the screw A, is loosened slightly. The correct number of holes may be counted and the sector arms set to include them; or better, the graduations on the dial may be used in connection with the tables given on pages 210 to 218. To set the sector arms by this last method, follow down the column headed "Graduation" in the tables referred to, until opposite the number of divisions that is desired. Take the number that is found here and set the arms by bringing the left one against the index pin, which should be inserted in any convenient hole in the required circle, and moving the right one until the graduation corresponding to the number obtained from the table coincides with the zero on the left arm. The correct number of holes will then be contained between the two arms, and counting is unnecessary.

When setting the arms by counting the holes, the left arm should be brought against the index pin as directed above, and then the required number of holes for each division should be counted from the hole that the pin is in, considering this hole as zero.

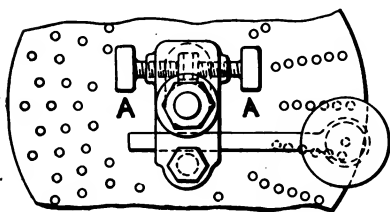


Fig. 6

Adjustable Index Crank. The index crank of the spiral head is adjustable circumferentially. This is shown in Fig. 6. Many times it is desired to make a delicate adjustment of the work, or to bring the index pin to the nearest hole without disturbing the setting of the work. To adjust

the index crank after the work has been placed in position, turn thumb screws A-A, Fig. 6, until the pin enters the nearest hole in the index plate. To rotate the work relative to the index plate, both the stop pin at the back of the plate and the index crank pin should be engaged, the adjustment being made by means of the thumb screws as before.

Throwing Worm Out of Mesh. When it is desired to turn the spindle by hand and index work by means of the plate on the front end of the spindle, it is necessary to disengage the driving worm A, Fig. 4. To do this, turn the knob E, by means of a pin wrench furnished, about one-quarter of a revolution in the reverse direction to that indicated by an arrow stamped on the knob. This will loosen nut G, that clamps eccentric bushing H; then with the fingers turn both knobs E and F, at the same time, and the bushing H, will revolve,

disengaging the worm from the wheel. To re-engage the worm, reverse the above operation.

Effect of Change in Angle of Elevation on Spindle. If the angle of the spiral head spindle is changed during operation, the spindle must be rotated slightly to bring the work back to the proper position, for when the spindle is elevated or depressed, the worm wheel is rotated about the worm, and the effect is the same as if the worm were turned.

Foot-stock. The foot-stock shown in Fig. 7 is for supporting pieces of work that are milled on centres or the outer ends of arbors, and pieces that are clamped in a chuck. The centre is adjustable longitudinally, and can be elevated or depressed by means of a rack V, and pinion actuated by hex U. It can also be set at an angle out of parallel with the base when it is desired to mill drills, taper reamers, etc., so that it can be kept in perfect alignment with the spiral head

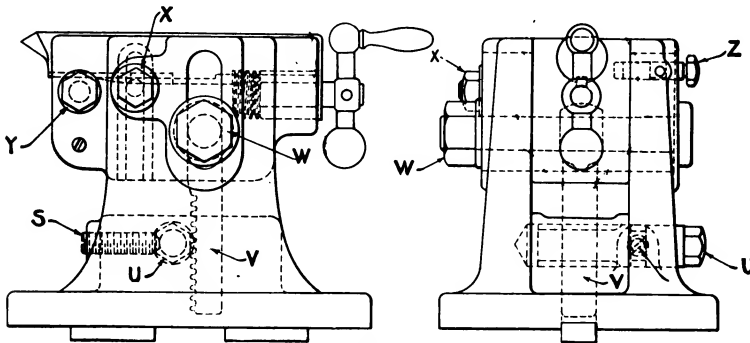


Fig. 7

centre. The advantage of this is readily appreciated from the fact that by the use of centres that cannot be adjusted, work is apt to become cramped at certain positions during its revolution, and, as a result, even spacing cannot be obtained.

When set in any position, the centre is firmly held by means of the nuts W, X and Y. Set screw S prevents endwise movement of the elevating pinion.

Two taper pins, one of which is shown at Z, are used to quickly and accurately locate the foot-stock centre in line with the spiral head centre, when the centres are parallel to the top of the table. They may be loosened by twisting a little with a wrench.

Fig. 8 shows a gauge that is very handy to use for quickly adjusting the foot-stock centre in line with the spiral head centre

when setting for taper work. It consists of a bushing that fits over the centre in the spiral head and a blade, the bottom edge of which is the same distance above the centre as the top of the foot-stock centre.

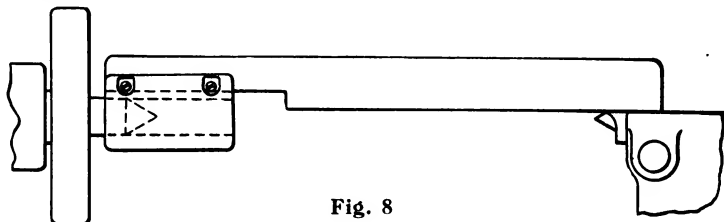


Fig. 8

INDEXING

The first office of the spiral head is to index or divide the periphery of a piece of work into a number of definite or given parts. This is accomplished by means of the index crank and the index plates furnished with the head; or, in the case of some of the more common coarse divisions, by means of the rapid index plate fastened to the nose of the spindle.

There are two practical and accurate methods of indexing, known as Plain and Differential. A third method, known as the Compound, was used extensively in the past, and is still employed by some shops having machines that are not fitted for Differential indexing. The chances for errors in making the complicated indexing moves, and the fact that even when the moves are made correctly, exact results cannot be obtained, causes the Compound method to be of little practical value where accurate spacing is required. It has, as a result, been largely superseded by the Differential method, by which the same numbers can be indexed accurately, and with little liability of errors in making the indexing moves.

Most spiral heads that are not fitted for Differential indexing can be at a nominal cost, and the unusual simplicity and convenience of this method in themselves are sufficient to warrant doing this.

By the Plain method of indexing, which includes rapid indexing, using the plate on the spindle nose, all divisions up to 50, even numbers up to 100, except 96, and many numbers that are multiples of 5 up to 380, besides many others, can be indexed with the three index plates furnished. With the addition of the change gears furnished, divisions obtained by Plain indexing, together with those that cannot be obtained by that method, from 1 to 382, and many others beyond, can be indexed by the Differential method.

Plain and Direct Indexing. Plain indexing on the spiral head is very similar to indexing with ordinary index centres. It depends entirely upon how many times the index crank must be turned to cause the work to make one revolution. When this ratio is known, it is an easy matter to calculate the number of turns or fractions of a turn of the index crank to produce a given number of spaces on the periphery of the work.

The worm wheel on the spindle contains 40 teeth and the worm is single threaded, hence for every turn of the index crank, the worm wheel is advanced one tooth, or the spindle makes $\frac{1}{40}$ part of a revolution. This should be remembered, for it is used in all indexing calculations on the spiral head. If the crank is turned 40 times, the spindle and work will make one complete revolution. To find how many turns of the crank are necessary for a certain division of the work, 40 is divided by the number of the divisions which are desired. The quotient will be the number of turns, or the part of a turn of the crank, which will give each desired division. Applying this rule, 40 divisions would be made by turning the crank completely around once for each division, or 20 divisions would be obtained by turning around twice. When the quotient contains a fraction, or is a fraction, it will be necessary to give the crank a part revolution in indexing. The numerator of the fraction represents the number of holes that should be indexed for each division. If the fraction is so small that none of the plates contains the number of holes represented by the denominator, both numerator and denominator should be multiplied by a common multiplier that will give a fraction, the denominator of which represents a number of holes that is available. On the other hand, if the fraction is of large terms, it should be reduced so that its denominator will represent a number of holes that is available. For example, seven divisions are desired. 40 divided by 7, equals $5\frac{5}{7}$ turns of the index crank to each division. There is no plate containing so few holes as 7, so this should be raised. Multiplying by the common multiplier 3, we have $\frac{5}{7} \times 3 = \frac{15}{7}$. Hence, for one division of the work, the index crank pin is placed in the 21 hole circle, and the crank is given 5 complete revolutions and then is moved ahead 15 additional holes. 35 holes in the 49 hole circle might also be used in place of 15 in the 21 hole circle, as $\frac{15}{7}$ is a multiple of the original fraction $\frac{5}{7}$.

The tables on pages 210 to 218 give the correct circles of holes and numbers to index for each division of all numbers that are obtainable by plain indexing, as well as those obtainable by the differential

method, and when these are used figuring, such as that above, is unnecessary.

Indexing in Degrees and Parts of Degrees. When it is desired to divide the circumference of a piece in this manner, it can often be done by plain indexing. One complete turn of the index crank produces $\frac{1}{40}$ of a turn of the work, or $\frac{360^\circ}{40} = 9$ degrees. Following this method:

2 holes in the 18-hole circle = 1 degree.

2 holes in the 27-hole circle = $\frac{2}{3}$ degree.

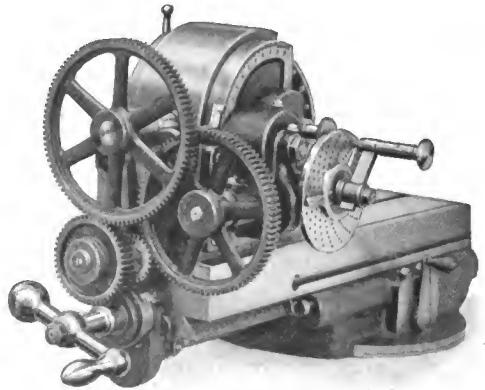
1 hole in the 18-hole circle = $\frac{1}{2}$ degree.

1 hole in the 27-hole circle = $\frac{1}{3}$ degree.

Other odd fractional parts of a degree can be easily found by dividing the number of holes in any given circle into 9 degrees. It will be noticed that $\frac{1}{4}$ degree spacing cannot be obtained in this way; but with differential indexing, as explained on page 57, it is easy to get $\frac{1}{4}$ degree and other fractional spacings.

Differential Indexing. Differential indexing enables a wide range of divisions to be indexed, which cannot be obtained by plain indexing. With the change gears and three index plates furnished with the spiral head, it is possible to index all numbers, not obtainable by plain indexing, from 1 to 382; in addition, many other divisions beyond 382 can be indexed.

By this method, the index crank is moved in the same circle of holes, and the operation is like that of plain indexing. The spiral head spindle and index plate are connected by a train of gearing, as shown above, and the stop pin at the back of the plate is thrown out. As the index crank is turned, the spindle is rotated through the worm and wheel, and the plate moves either in the same or opposite direction to that of the crank. The total movement of the crank at every indexing is, therefore, equal to its movement relative to the plate, plus the movement of the plate, when the plate revolves in the same direction as the crank,



Spiral Head Geared for Differential Indexing

or minus the movement of the plate, when the plate revolves in the opposite direction to the crank. The spiral head cannot be used for cutting spirals, when it is geared for differential indexing, for when cutting spirals the head is geared to the table feed screw.

To obviate the necessity of figuring out the change gears every time a certain number of divisions is required, tables on pages 210 to 225 have been compiled. By use of these tables, all numbers obtainable by differential indexing, together with those that can be had by the plain method can be easily indexed. The tables also give the correct circle and number of holes to be indexed, graduations for setting of the index sector, and the proper change gears to use.

In order to select the proper change gears, it is first necessary to find the ratio of the required gearing between the spindle and plate. After this has been done, the correct gears can be found. The following formulae show the manner in which this gearing is calculated.

N = number of divisions required.

H = number of holes in index plate.

n = number of holes taken at each indexing.

V = ratio of gearing between index crank and spindle.

x = ratio of the train of gearing between the spindle and the index plate.

S = gear on spindle. } Drivers.

G_1 = first gear on stud. }

G_2 = second gear on stud. } Driven.

W = gear on worm.

$$x = \frac{HV - Nn}{H} \text{ if } HV \text{ is greater than } Nn.$$

$$x = \frac{Nn - HV}{H} \text{ if } HV \text{ is less than } Nn.$$

$$x = \frac{S}{W} \text{ (for simple gearing).}$$

$$x = \frac{S G_1}{G_2 W} \text{ (for compound gearing).}$$

V is equal to 40 on the B. & S. spiral head, and the index plates furnished have the following numbers of holes: 15, 16, 17, 18, 19, 20, 21, 23, 27, 29, 31, 33, 37, 39, 41, 43, 47, 49.

The gears furnished have the following numbers of teeth: 24 (2 gears), 28, 32, 40, 44, 48, 56, 64, 72, 86, 100.

In selecting the index circle to be used, it is best to select one with a number having factors that are contained in the change gears

on hand, for if H contains a factor not found in the gears, x cannot usually be obtained, unless the factor is canceled by the difference between HV and Nn , or unless N contains the factor.

When HV is greater than Nn and gearing is simple, use 1 idler.

When HV is greater than Nn and gearing is compound, use no idlers.

When HV is less than Nn and gearing is simple, use 2 idlers.

When HV is less than Nn and gearing is compound, use 1 idler.

Select " n " so that the ratio of gearing will not exceed 6:1 on account of the excessive stress upon the gears.

A few examples are given herewith to illustrate the application of the above formulae:

Example 1:

$N = 59$. Required H , n and x .

Assume $H = 33$, $n = 22$.

$$\text{Then } x = \frac{(33 \times 40) - (59 \times 22)}{33} = \frac{22}{33} = \frac{2}{3}.$$

We now select gears giving this ratio, as 32 and 48, the 32 being the gear on spindle and the 48 the gear on worm. HV is greater than Nn , and the gearing is simple, requiring 1 idler.

Example 2:

$N = 319$. Required H , n and x .

Assume $H = 29$, $n = 4$.

$$\text{Then } x = \frac{(319 \times 4) - (29 \times 40)}{29} = \frac{11.6}{29} = \frac{1}{25}.$$

When the ratio is not obtainable with simple gearing, try compound gearing.

$\frac{1}{25}$ can be expressed as follows:

$$\frac{3 \times 4}{1 \times 3} \text{ or } \frac{72 \times 64}{24 \times 48}$$

for which there are available gears.

HV is less than Nn and the gearing is compound, requiring 1 idler.

Head Geared for 271 Divisions

Fig. 9 shows the spiral head geared, simple gearing, for 271 divisions. Referring to the table on page 216, the gears called for are: C, 56 teeth, and E, 72 teeth, with

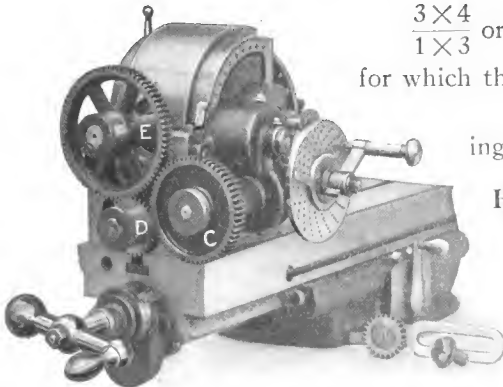


Fig. 9

one idler D. The idler D serves to rotate the index plate in the same direction as the crank, thus in making 280 turns of the crank, nine divisions are lost, giving the correct number of divisions, 271. The sector should be set to indicate $\frac{1}{4}$ turns, or 3 holes in the 21 hole circle, and the head is ready for 271 divisions, the indexing being made the same as for plain indexing.

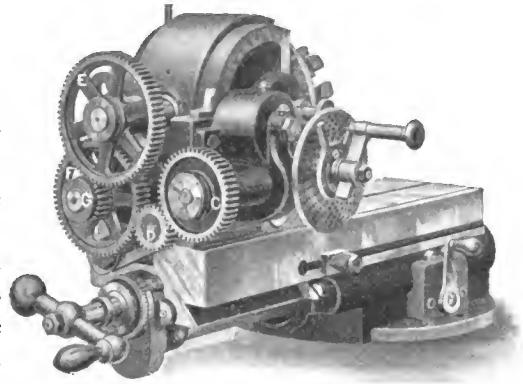


Fig. 10

Head Geared for 319 Divisions.

Fig. 10 shows the spiral head geared, compound gearing, for 319 divisions. Referring to the table on page 217, the gears called for are: C, 48 teeth; F, 64 teeth; G, 24 teeth; E, 72 teeth and one idler D, 24 teeth. The sector should be set to $\frac{1}{9}$ turns, or 4 holes in the 29 circle; the head is then ready for 319 divisions.

Spacing for Quarter Degrees.

Example 3.

Required H , n and x for spacing $\frac{1}{4}$ degrees, or 1440 divisions.

Assume $H = 33$, $n = 1$.

$$\text{Then } \frac{(1440 \times 1) - (33 \times 40)}{33} = \frac{120}{33} \text{ or } \frac{64 \times 100}{40 \times 44}$$

One idler is required.

The following table gives data required for spacing $\frac{1}{2}^\circ$ and $\frac{1}{4}^\circ$. For fractional parts of degrees obtainable by plain indexing see page 54.

Divisions	Index Circle	No. of Turns of Index	Graduation	Gear on Worm	No. 1 Hole		Gear on Spindle	Idlers	
					1st Gear on Stud	2d Gear on Stud		No. 1 Hole	No. 2 Hole
$\frac{1}{2}^\circ$	49	$\frac{1}{49}$		28	64	56	100		24
$\frac{1}{4}^\circ$	33	$\frac{1}{33}$		44	64	40	100		24

Aliquant or Fractional Spacing.

Example 4:

Required: A Vernier to read to $\frac{1}{2}$ degree or five minutes, the scale being divided to degrees.

Each Vernier space can equal $\frac{1}{2}$ degree.

$$\frac{11 \times 1}{12 \times 360} = \frac{11}{4320} \text{ or } \frac{4320}{11} \text{ spaces in whole circle} = 392\frac{8}{11} \text{ spaces.}$$

Assume $H=18$, $n=2$.

$$\text{Then } \frac{(392\frac{8}{11} \times 2) - (18 \times 40)}{18} = \frac{720/11}{18} = \frac{720}{11} \times \frac{1}{18} = \frac{40}{11} = \frac{64 \times 100}{40 \times 44}$$

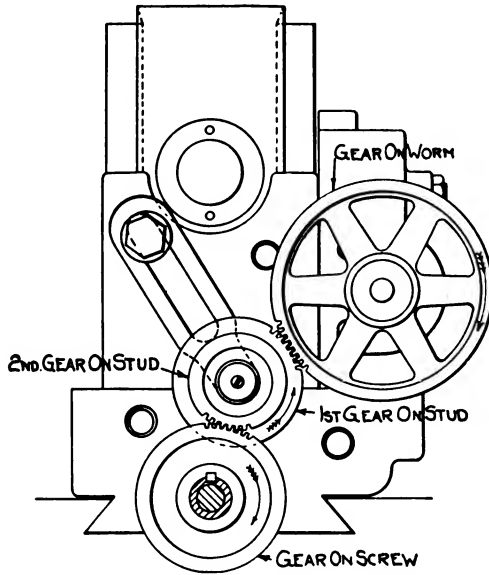
One idler is required.

CUTTING SPIRALS.

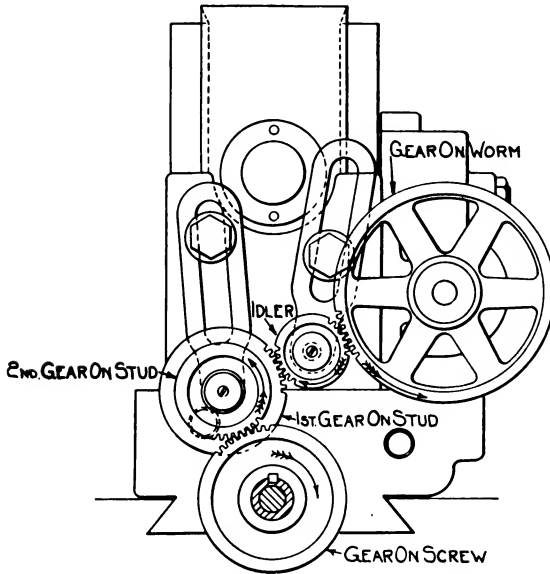
Spirals that are most commonly cut on milling machines embrace spiral gears, spiral mills, counterbores, and twist drills. Worms are also cut with the aid of a vertical spindle or universal milling attachment. Examples of some of these classes of work are shown in this chapter, and in operations in chapters VIII and IX.

The method of producing the spiral movement of the work has been described before, and the manner in which the head is geared is shown in Figs. 11 and 12. The four change gears are known as: *gear on screw*; *first gear on stud (as it is the first to be put on)*; *second gear on stud*; and *gear on worm*. The screw gear and first gear on stud are the drivers, and the others are the driven gears. By using different combinations of the change gears furnished, the ratio of the longitudinal movement of the table to the rotary movement of the work can be varied; in other words, the leads of the spirals it is possible to cut are governed directly by these gears. Usually they are of such ratio that the work is advanced more than an inch while making one turn, and thus the spirals cut on milling machines are designated in terms of inches to one turn, rather than turns, or threads per inch; for instance, a spiral is said to be of 8 inches lead, not that its pitch is 1-8 turn per inch.

The feed screw of the table has four threads to the inch, and forty turns of the worm make one turn of the spiral head spindle; accordingly, if change gears of equal diameter are used, the work will make a complete turn while it is moved lengthwise 10 inches; that is, the spiral will have a lead of 10 inches. This is the lead of the machine, and it is the resultant of the action of the parts of the machine that are always employed in this work, and is so regarded in making the calculations used in cutting spirals.

**Fig. 11**

Showing Gearing When No Idler is Required

**Fig. 12**

Showing Gearing With Idler in Use

Principle same as for Change Gears of a Lathe. In principle, these calculations are the same as for change gears of a screw cutting lathe. The compound ratio of the driven to the driving gears equals in all cases, the ratio of the lead of the required spiral to the lead of the machine. This can be readily demonstrated by changing the diameters of the gears.

Gears of the same diameter produce, as explained above, a spiral with a lead of 10 inches, which is the same lead as the lead of the machine. Three gears of equal diameter and a driven gear double this diameter, produce a spiral with a lead of 20 inches, or twice the lead of the machine; and with both driven gears, twice the diameters of the drivers, the ratio being compound, a spiral is produced with a lead of 40 inches, or four times the machine's lead. Conversely, driving gears twice the diameter of the driven produce a spiral with a lead equal to $\frac{1}{4}$ the lead of the machine, or $2\frac{1}{2}$ inches.

$$\frac{\text{Driven Gears}}{\text{Driving Gears}} = \frac{\text{Lead of Required Spiral}}{\text{Lead of Machine}}$$

or, as the product of each class of gears determines the ratio, the head being compound geared, and as the lead of the machine is ten inches,

$$\frac{\text{Product of Driven Gears}}{\text{Product of Driving Gears}} = \frac{\text{Lead of Required Spiral}}{10} \quad \text{That is,}$$

the compound ratio of the driven to the driving gears may always be represented by a fraction whose numerator is the lead to be cut and whose denominator is 10. In other words, the ratio is as the required lead is to 10; for example, if the required lead is 20, the ratio is 20:10. To express this in units instead of tens, the ratio is always the same as one-tenth of the required lead is to 1. And frequently this is a very convenient way to think of the ratio; for example, if the lead is 40, the ratio of the gears is 4:1. If the lead is 25, the gears are 2.5:1, etc.

To illustrate the usual calculations, assume that a spiral of 12 inch lead is to be cut. The compound ratio of the driven to the driving gears equals the desired lead divided by 10, or it may be represented by the fraction $\frac{12}{10}$. Resolving this into two factors to represent the two pairs of change gears, $\frac{12}{10} = \frac{3}{2} \times \frac{4}{5}$. Both terms of the first factor are multiplied by such a number (24 in this instance) that the resulting numerator and denominator will correspond with the number of teeth of two of the change gears furnished with the machine (such multiplications not affecting the value of a fraction) $\frac{3}{2} \times \frac{24}{24} = \frac{72}{48}$. The second factor is similarly treated: $\frac{4}{5} \times \frac{24}{24} = \frac{96}{120}$, and the gears with

72, 32, 48 and 40 teeth are selected. $\frac{12}{10} = \left(\frac{72 \times 32}{48 \times 40} \right)$

The first two are the driven, and the last two the drivers, the numerators of the fractions representing the driven gears. The 72 is the worm gear, 40 the first on stud, 32 the second on stud and 48 the screw gear. The two driving gears might be transposed, and the two driven gears might also be transposed without changing the spiral. That is, the 72 could be used as the second on stud and the 32 as the worm gear, if such an arrangement were more convenient. The following rules express in abridged form the methods of figuring change gears to cut given spirals, and of ascertaining what spirals can be cut with change gears.

Rules for Obtaining Ratio of the Gears Necessary to Cut a Given Spiral. Note the ratio of the required lead to 10. This ratio is the compound ratio of the driven to the driving gears. Example: If the lead of required spiral is 12 inches, 12 to 10 will be the ratio of the gears.

Or, divide the required lead by 10 and note the ratio between the quotient and 1. This ratio is usually the most simple form of the compound ratio of the driven to the driving gears. Example: If the required lead is 40 inches, the quotient is $40 \div 10$ and the ratio 4 to 1.

Rule for Determining Number of Teeth of Gears Required to Cut a Given Spiral. Having obtained the ratio between the required lead and 10 by one of the preceding rules, express the ratio in the form of a fraction; resolve this fraction into two factors, raise these factors to higher terms that correspond with the teeth of gears that can be conveniently used. The numerators will represent the driven and the denominators the driving gears that produce the required spiral. For example: What gears shall be used to cut a lead of 27 inches?

$$\frac{27}{10} = \frac{3}{1} \times \frac{9}{10} = \left(\frac{3}{1} \times \frac{1}{1} \right) \times \left(\frac{9}{10} \times \frac{1}{1} \right) = \frac{48 \times 72}{32 \times 40}$$

From the fact that the product of the driven gears divided by the product of the drivers equals the lead divided by 10, or one-tenth of the lead, it is evident that ten times the product of the driven gears divided by the product of the drivers, will equal the lead of the spiral. Hence the rule:

Rule for Ascertaining what Spiral May be Cut by Any Given Change Gears. Divide ten times the product of the driven gears by the product of the drivers, and the quotient is the lead of the resulting spiral in inches to one turn. For example: What spiral

will be cut by gears, with 48, 72, 32 and 40 teeth, the first two being used as driven gears? Spiral to be cut equals $\frac{10 \times 48 \times 72}{32 \times 40} = 27$ inches to one turn.

This rule is often of service in determining what spirals may be cut with the gears the workman chances to have at hand.

The tables on pages 226 to 228 give the leads and approximate angles of some spirals produced by the gears furnished with our machines, and the combination of gears given in each case is such that they will properly mesh with one another. The tables on pages 229 to 247 contain all the leads that can be obtained with any possible combination of the change gears furnished, even though some of the leads are not available for use on account of the gears interfering or not reaching. Combinations of gears that are too small in diameter to reach for right-hand spirals, can generally be used for left-hand spirals, as the reverse gear is then required and will enable the gears to reach.

As we have already mentioned, the two driving gears, or the two driven gears of any combination can be transposed, but a driver must not be substituted for a driven or vice versa. Four different arrangements of the gears of any combination are thus possible, without changing the ratio, and when one arrangement interferes, or will not reach, the others should be tried. Thus, the gears to give a lead of 3.60" are: drivers, 100 teeth and 32 teeth; driven, 24 teeth and 48 teeth. By transposing the gears, the following four arrangements may be obtained.

Drivers.		1st	2nd	3rd	4th
Gear on Screw		100	32	100	32
1st Gear on Stud		32	100	32	100
Driven.					
2nd Gear on Stud		24	24	48	48
Gear on Worm		48	48	24	24

The first arrangement, however, is found by actual test to be the only one available, owing to the interference of the gears in the other combinations preventing their meshing properly.

When very short leads are required, it is preferable to disengage the worm wheel and connect the gearing directly to the spiral head spindle (using the differential indexing centre). This method gives leads one-fortieth of the leads given in the table for the same combinations of gears. Thus, for a lead of 6.160", the table calls for gear on worm,

56 teeth; 1st gear on stud, 40 teeth; 2nd gear on stud, 44 teeth; and gear on screw, 100 teeth. Putting the 56 tooth gear on the spindle instead of on the worm, gives a lead of $\frac{6.160}{40} = .154''$.

By this method, very short leads may be obtained without excessively straining the mechanism, but the regular means of indexing the work cannot be employed. A method that can be used for indexing when using the differential centre is to have the number of teeth in the gear on the spindle some multiple of the number required to

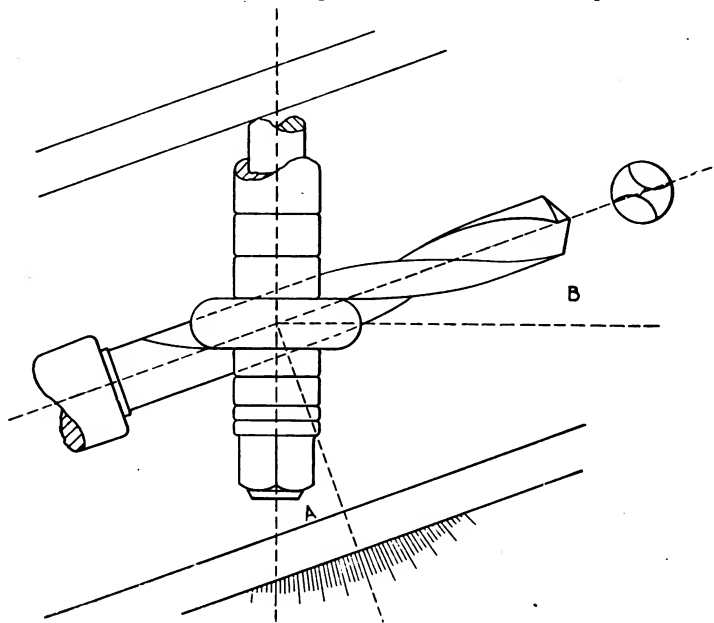


Fig. 13

be indexed. Swing the gears out of mesh and advance the gear on spindle the number of teeth required to index the work one division at each indexing. Thus, if 9 divisions are required with a lead of $.261''$, we select a lead from the table equal to about $.261'' \times 40 = 10.440''$, when the gear on worm (which will now be the gear on spindle) is some multiple of 9, as 72. The nearest lead is $10.467''$, which gives $\frac{10.467}{10} = .2617''$ lead, giving an error of $.0007''$. To index the work, the gear on spindle is advanced $7\frac{2}{9} = 8$ teeth at each indexing.

The short lead attachment described in the next chapter can also be used to cut short leads, an index plate being provided for use in cutting multiple threads.

Position of the Table in Cutting Spirals. The change gears having been selected, the next step in cutting spirals is to determine the position at which the table must be placed to bring the spiral in line with the cutter as the work is being milled.

The correct position of the table is indicated by the angle shown at A, Fig. 13, and this angle, as may be noticed from that figure, has the same number of degrees as the angle B, which is termed the angle of the spiral, and is formed by the intersection of the spiral and a line parallel with the axis of the piece being milled. The reason the angles A and B are alike, is that their corresponding sides are perpendicular to each other.

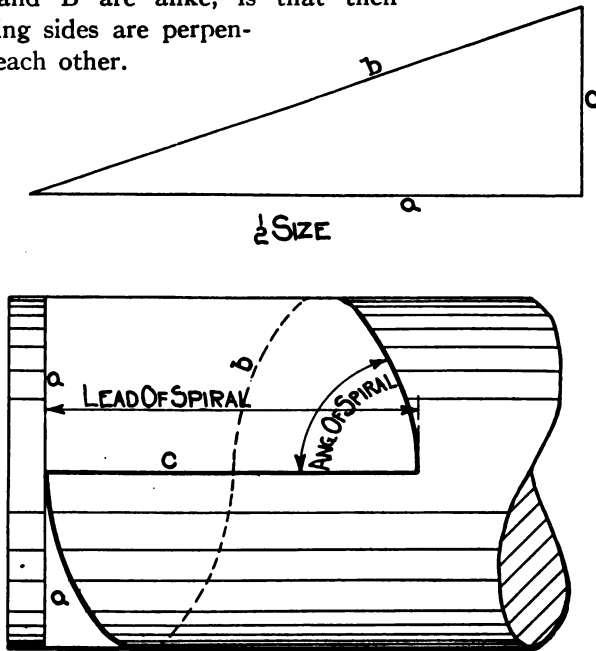


Fig. 14

The angle of the spiral depends upon the lead of the spiral and the diameter of the piece to be milled. The greater the lead of a spiral of any given diameter, the smaller the angle, and the greater the diameter of any spiral with a given lead, the greater the spiral angle.

If the angle wanted is not found in the tables on pages 226 to 228, it can be ascertained in two ways, graphically or more conveniently, by a simple calculation and reference to the tables on pages 309 to 317. In determining it graphically, a right-angle triangle is drawn to scale.

One of the sides which forms the right angle represents the circumference of the piece in inches, and the hypotenuse represents the line of the spiral. The angle between the lines representing the path of the spiral and the lead of the spiral is the angle of the spiral. This angle can be transferred from the drawing to the work by a bevel protractor, or even by cutting a paper templet and winding it about the work as shown in Fig. 14. The machine is then set so that the spiral or groove as it touches the cutter will be in line with the cutter. Or the angle may be measured and the saddle set to a corresponding number of degrees by the graduations on the base.

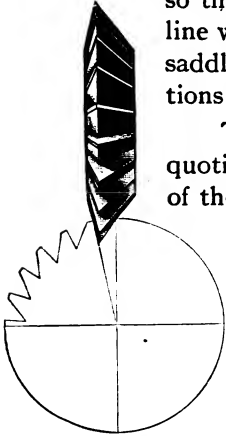


Fig. 15 more accurate, and there is less liability of error than with the first. The saddle can be set to the proper angle, but before cutting into the blank, it is well to let the mill just touch the work, then run the work along by hand and make a slight spiral mark, and by this mark see whether the change gears give the right lead.

Special care should be taken in cutting spirals that the work does not slip, and when a cut is made it is well to drop the work away from the mill while coming back for another cut, or the mill may be stopped and turned to such a position that the teeth will not touch the work while the table is brought back preparatory to another cut.

Setting Cutter Central. In making such cuts as are alike on both sides, for instance, the threads of worms or the teeth of spiral gears, care must be taken to set the work centrally perpendicular with the centre line of the cutter before swinging the saddle to the angle of the spiral.

Cuts that have one face radial, especially those that are spiral, are best made with an angular cutter of the form shown in Fig. 15, as cutters of this form readily clear the radial face of the cut, keep sharp for some time and produce a smooth surface.

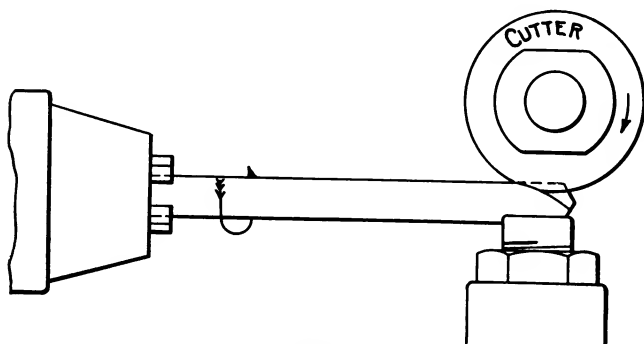


Fig. 16

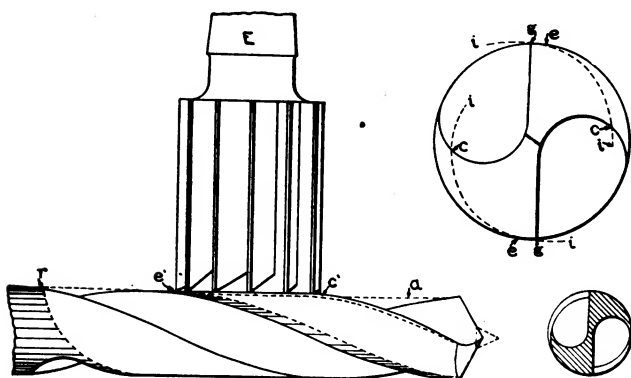


Fig. 17

Twist Drills. The operation of milling a twist drill is shown in Fig. 16. The drill is held in a collet, or chuck, and, if very long, is allowed to pass through the spindle of the spiral head. The cutter is brought directly over the centre of the drill, and the table is set at the angle of spiral.

The depth of groove in a twist drill diminishes as it approaches the shank, in order to obtain increased strength at the place where the drill generally breaks. The variation in depth is conditional, depending mainly on the strength it is desirable to obtain, or the usage the drill is subject to. To secure this variation in the depth of the groove, the spiral head spindle is elevated slightly, depending on the length of the flute and diameter of the drill.

The outer end of the drill is supported by the centre rest, and when quite small, should be pressed down firmly, until the cutter has passed over the end.

The elevating screw of this rest is hollow, and contains a small centre piece with a V groove cut therein to aid in holding the work central. This piece may be made in other shapes to adapt it to special work.

Another, and very important operation on the twist drill, is that of "backing off" the rear of the lip, so as to give it the necessary clearance, to prevent excessive friction during drilling. In the illustration, Fig. 17, the saddle is turned about one-half degree as for cutting a right-hand spiral, but as the angle depends on several conditions, it will be necessary to determine what the effect will be under different circumstances. A slight study of the figure will be sufficient for this, by assuming the effect of different angles, mills and the pitches of spirals. The object of placing the saddle at an angle is to cause the mill E to cut into the lip at c', and have it just touch the surface at e'. The line r being parallel with the face of the mill, the angular deviation of the saddle is shown at a, in comparison with the side of the drill.

From a little consideration it will be seen that while the drill has a positive traversing and rotative movement, the edge of the mill at e' must always touch the lip at a given distance from the front edge; this being the vanishing point, if such we may call it. The other surface forming the real diameter of the drill is beyond reach of the cutter, and is so left to guide and steady it while in use. The point e, shown in the enlarged section, shows where the cutter commences, and its increase until it reaches a maximum depth

at c, where it may be increased or diminished according to the angle employed in the operation, the line of cutter action being represented by ii.

Before backing off, the surface of the smaller drills in particular should be colored with a solution of sulphate of copper, water and sulphuric acid. This solution can be applied with a piece of waste, and will give the piece a distinct copper color. The object of this is to clearly show the action of the mill on the lip of the drill, for, when satisfactory, a uniform streak of coppered surface the full length of the lip from the front edge g back to e, is left untouched by the mill.

The above-mentioned coloring solution can be made by the following formula:

Sulphate of copper (saturated solution).....	4 oz.
Water.....	8 oz.
Sulphuric acid.....	1 oz.

It is sometimes preferred to begin the cut at the shank end. By starting the cut in at this end, the tendency to lift the drill blank from the rest is lessened.

The table given on page 326 is useful for determining the cutters, pitches, gears and angles for twist drills.

Cutting Left-Hand Spirals. When giving directions for cutting spirals in any of the foregoing pages, right-hand spirals are at all times referred to. For the production of left-hand spirals, the only changes necessary are the swinging of the saddle to the opposite side of the centre line, and the introduction of an intermediate gear upon the stud, Fig. 12, to engage with either pair of change gears for changing the direction of rotation of the spiral head spindle.

Cutting Spirals with an End Mill. When spirals cannot be conveniently cut with side or angular milling cutters, as previously described, it is sometimes convenient to use end mills, as for example, when the diameter of the piece is very large, or the spiral is of such a lead that the table cannot be set at the requisite angle, the work is so held that its centre and that of the mill will be in the same plane and the saddle is set at zero.

CHAPTER V

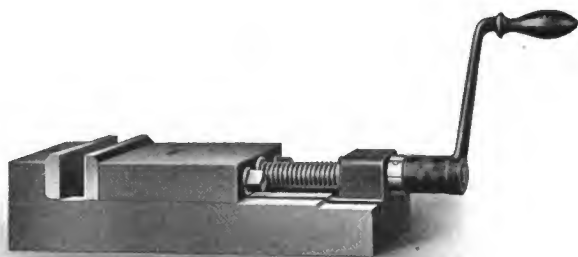
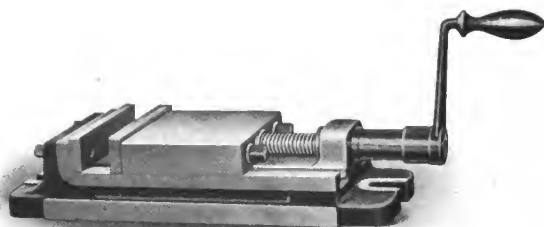
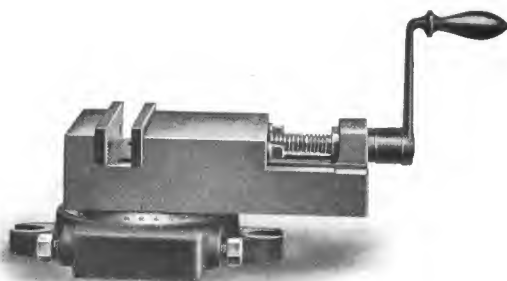
Attachments

A milling machine is, in itself, a most versatile tool, but when equipped with a suitable set of attachments, the range of work that can be done is greatly increased. Also there are often milling operations that can be performed without an attachment, but by using one the jobs can be more easily and quickly done. Attachments are, therefore, most desirable auxiliaries where a machine is not confined to one manufacturing operation, but is used for general milling purposes. And even in manufacturing, where a machine is kept on one operation, an attachment can often be used to good advantage.

Broadly speaking, the variety of attachments for use on milling machines is almost limitless. To fully realize this, one has only to visit several shops producing different kinds of work on milling machines, and observe the methods employed. Devices of every conceivable description will be seen in use in connection with the machines, and, while many of them may be of a more or less special character and adaptable only to a particular operation, they are, strictly speaking, attachments. Some of these devices, however, are so designed that quite a number of different operations can be performed by their use, or the same operation can be repeated on a variety of pieces. It is these mechanisms that we are accustomed to regard more especially as attachments, while those designed for single operations are almost universally known in shops as fixtures. It would be useless to attempt to treat of the latter, as their designs and purposes are as varied as the different lines of mechanical work.

The efficiency of attachments, like machines, depends largely upon their design and construction, and a poorly designed or built mechanism of this type can seriously impair the quality of work and thus defeat its own object.

Many forms of attachments designed for the same purpose will be found, as it is necessary for every manufacturer to adapt attachments to his machine. This is a matter of minor importance, however, and a close examination will reveal that, as a general rule, the principles of the different mechanisms are similar. This chapter is devoted to

**Fig. 18****Fig. 19****Fig. 20**

our line of attachments, as typical of attachments in general, with brief descriptions of their general designs and functions. From this information it is hoped that the reader will be able to understand the necessity for, and advantages of, these mechanisms.

Vises. While vises are furnished as a part of the regular equipment of most milling machines, and for that reason are not styled as attachments, notwithstanding this, they may be so properly classed.

Vises are useful for holding a large variety of small work while it is being milled or planed. Numerous illustrations of their employment can be found in the examples of operations throughout Chapters VII and IX. It is essential that they be as rigid as possible, and to this end should be built with well-designed, strong, close-fitting parts. It is well to have them set low so as to bring the work close to the table.

There are several styles of vises. Fig. 18 shows a Plain Vise, for lighter operations. The bed and slide are of cast iron, while the jaws are tool steel, hardened and ground. It is fastened to the surface of the table by means of a screw that passes through the bed and threads into a nut inserted in a table T slot. The head of the clamping screw fits a counterbore in the vise bed, and is flush with the top of the casting, so that it does not interfere with the movement of the sliding jaw.

The vise shown in Fig. 19 is known as a Flanged Vise, and differs little from the Plain Vise except in the method of clamping to the table. A slotted flange is provided at each end for this purpose, and regular T slot bolts with nuts and washers are employed. Also a pair of straps are furnished for clamping the vise at the sides when this is necessary.

It is sometimes desired to mill angular or tapering work. A vise provided with a swivel, and known by that name, is shown in Fig. 20, and by its use this work can be readily done. The vise proper is of the same design as the plain vise, but the bottom of the bed fits into a split ring in a base. This ring is tapered on the inside to draw the bed to its seat, and holds it rigidly without disturbing the alignment. The split ring is closed by either one of the two clamping bolts at the side, two being provided for convenience in setting. The entire circumference of the base is graduated to degrees, and the vise can be readily swung to any angle to the table ways. The base is provided with flanges for fastening it to the surface of the table.

Fig. 21 shows a Tool Makers' Universal Vise, designed to meet the requirements of tool makers and machine shops where a great

variety of work is encountered. It is found of advantage for holding irregular or angular pieces and forms, also in determining and forming the edges for model parts of machines and work of a similar class. Often this vise will take the place of an expensive fixture. It can be set at any angle and the work placed in position or removed without disturbing the setting. It can also be easily removed from one machine to another and several operations performed without removing the piece of work. The base is double, and is fastened to the table by bolts that fit into the table T slots. It has two sets of bolt slots to allow for moving the vise back when set in a vertical plane. The upper part is a hinged knee, that swivels on the lower part of the base, and it

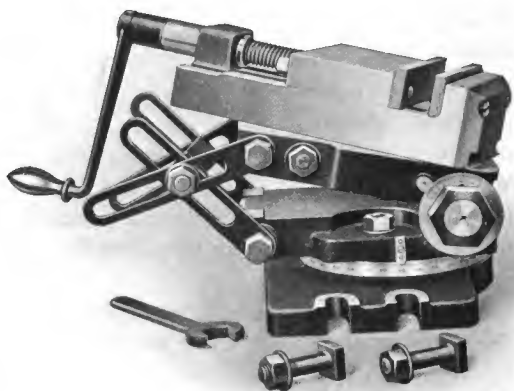


Fig. 21

can be set at any angle in a horizontal plane, graduations to degrees indicating the position. The top section of the knee is hinged to the lower part in such a manner that it can be set at any angle to 90° in a vertical plane, and clamped rigidly in position by the nut on the end of the bolt forming the hinge and by the bolt at the joint in the bracing levers. Graduations on a steel dial at the side of the vise indicate the elevation of the knee. A swiveling movement is also provided for the vise proper on the upper part of the hinged knee, and it can be set and clamped at any angle to the axis of the bolt forming the hinge.

Index Centres. These mechanisms are employed for obtaining exact spacing of more common numbers of divisions upon the periphery of pieces of work, such as in cutting the teeth of small gears, ratchets and cutters, fluting taps and reamers, milling the sides of nuts and heads of bolts, and various other purposes. They are used principally upon machines not fitted with a spiral head, for their functions in most instances can be equally well performed by the latter, which also offers many additional advantages.

Like other attachments, their efficiency is largely dependent upon their design, and it is important that they be exceedingly stiff,

in order that the work may be rigidly supported. They should also be convenient to operate, so that indexing may be quickly accomplished.

One of the simplest forms of index centres, known as Single Dial Index Centres, is shown in Fig. 22. It consists of a head-stock and foot-stock of solid construction. The spindle of the head-stock is turned by means of the hand-wheel, and the divisions are indicated on the periphery of an index plate fastened to the spindle near the hand-wheel. There are holes in the back of the index plate corresponding to the divisions on its periphery, and a hardened steel taper pin is provided that is forced into the bushings of these holes by a

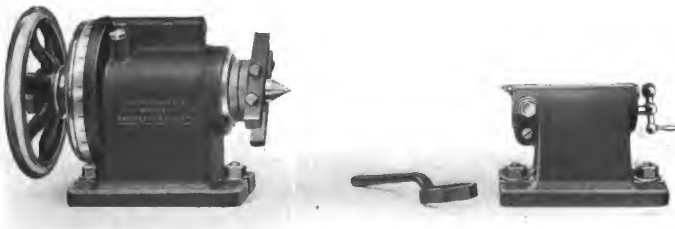


Fig. 22

spring, efficiently locking the spindle at any one of the divisions. The small lever near the top of the head-stock withdraws the taper pin when it is desired to index the work.

This style of index centres is found convenient whenever rapid indexing is to be done, as in cutting teeth in sprocket wheels and mills, or in milling grooves in taps, reamers and work of a similar kind. They are built in two sizes, one to accommodate work up to 8 inches diameter, and the other for work up to 12 inches diameter. The index plates or dials furnished have 24 divisions, or holes, but special plates having, for 8 inch centres, any number of holes up to 32, and, for 12 inch centres, any number up to 32, are sometimes made to order.

A common style of index centres, known as Plain Index Centres, is shown in Fig. 23. The spindle of the head-stock is revolved by means of a worm and wheel. The handle of the crank fastened to the worm shaft constitutes an index pin, and indexing is accomplished by means of a plate drilled with circles of different numbers of holes into which the spring pin of the crank fits. Thus it will be seen that the principle of indexing with these centres is the same as with the spiral head. For rapid indexing of the coarser divisions, the worm can be thrown out of mesh with the wheel and the spindle turned by hand; a circle

**Fig. 23**

of holes in the back of the worm wheel rim, and an index pin at the top of the head-stock provide for indexing when this is done.

These centres are built in sizes to accommodate work up to 10 inches and 12 inches diameter respectively. The nose of the spindle is threaded to receive a face plate or chuck. They are fitted with index sectors similar to those of the spiral head, and the index crank is adjustable so that it can be brought to the nearest hole without disturbing the setting. The index plates furnished divide all numbers to 50 and all even numbers to 100, except 96.

Fig. 24 shows a pair of Universal Index Centres. The resemblance between them and the spiral head is marked; in fact, the foot-stock is identical with that furnished with the latter mechanism. All operations upon centres that do not require other than plain indexing and where there is no spiral to be cut, can be performed with these centres equally as well as with a spiral head.

These universal index centres are built in six sizes, to accommodate work up to 6, 10, 12, $12\frac{1}{2}$, 14 and 15 inches diameter. Divisions are indexed by means of the index crank and plates, the same

**Fig. 24**

as on the spiral head. The two smaller sizes are arranged for rapid indexing of coarser divisions by disengaging the worm, and indexing with the plate fastened directly to the nose of the spindle, as on the spiral head. The index crank is adjustable and index sectors are employed. The index plates furnished with the 6 inch, 10 inch, 12 inch, 14 inch and 15 inch centres divide all numbers to 50, and all even numbers to 100, except 96; those furnished with the $12\frac{1}{2}$ inch centres divide all numbers to 100 and all even numbers to 134.

Index centres designed for manufacturing purposes where economy and rapidity of production are important factors, often have more than one spindle. Fig. 25 shows triple centres of this type. All three spindles of these centres are indexed simultaneously, and one thumb-screw firmly clamps them all, consequently three pieces of work can



Fig. 25

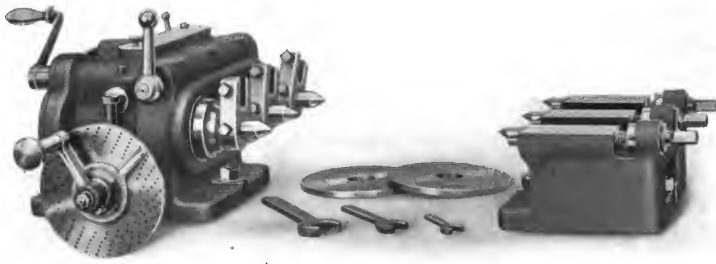
be finished in practically the same time it takes to machine one on single centres.

The spindles are rotated by a ratchet operated by the lever shown at the left of the head-stock. Indexing is accomplished by an index plate which divides all numbers as follows: 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 20 and 24. The index stop pin is shown at the left of the head-stock.

Using all three spindles, work up to $2\frac{1}{2}$ inches diameter can be taken; when only the two outside spindles are employed, work up to 5 inches diameter will swing.

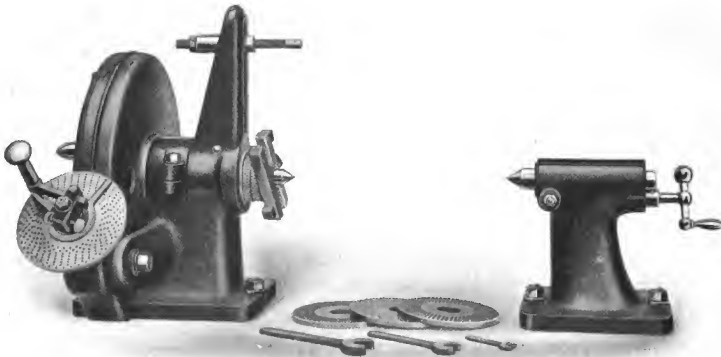
Triple index centres of the design that has the index plate at the side of the head-stock similar to the spiral head are shown in Fig. 26. Centres of this same general design, but arranged for rapid indexing only, are also built.

The index plates furnished with these centres divide all numbers to 50, even numbers to 100, except 96. When rapid indexing is desired, the worm of the index crank is disengaged and the centres are turned by means of a pinion actuated by the crank at the left of the head-stock; an index plate and stop pin provide for the divisions.

**Fig. 26**

The centres swing, using three spindles, 4 inches; using the two outside spindles, 8 inches.

Gear Cutting Attachment. The gear cutting attachment shown in Fig. 27 is useful for cutting spur gears of all diameters up to and including 16 inches, and is similar to ordinary index centres, only it

**Fig. 27**

will swing larger diameters. It is exceptionally rigid in construction and, to further insure steadiness to the gear while being cut, an adjustable rim rest is placed on the head-stock.

The worm and wheel of this attachment are accurately cut, and the wheel is of much larger diameter than that of ordinary index centres; consequently the possibility for error in spacing is materially lessened. The worm and worm wheel can be disengaged and the spindle turned by hand by means of the handle at the back, when setting or testing work.

The index plates furnished divide all numbers to 100, all even numbers to 134, and all numbers divisible by 4 to 200.

In addition to cutting gears, this attachment may be used on jig work where accurate indexing is an essential element. The spindle is threaded for the purpose of holding a chuck or face plate.

Vertical Spindle Milling Attachments. Vertical spindle milling attachments, including the Compound and Universal types, are used for a wide range of light and heavy milling, such as key seating, T slot cutting, spiral milling, face milling and work of a similar class; in fact, almost any operation that can be performed with a vertical spindle machine can be accomplished with a horizontal spindle machine when equipped with one of these attachments.



Fig. 28

In die sinking, as well as all kinds of surface milling, the advantage of having the work flat on the table and in plain sight of the operator is readily appreciated. For metal patterns and similar work, these attachments are especially valuable, as a line or template can be followed very closely, thus reducing the hand finishing to a minimum.

It is very essential in designing attachments of this kind, that ample provision be made for solidly clamping the mechanism to the machine, and unless this can be done, their value is greatly restricted. The method of clamping shown in the accompanying illustrations is such that the attachment becomes practically an integral part of the machine. To be practical, the method of clamping must also be simple, for much of the value of an attachment lies in the convenience with which it can be put on and taken off the machine.

In all cases, the spindles of the attachments illustrated can be set to any angle from a vertical to a horizontal position, the angle being indicated by graduations reading to degrees.

Attachments of this kind are usually driven from the machine spindle through bevel gears, but Fig. 28 shows one that is driven by

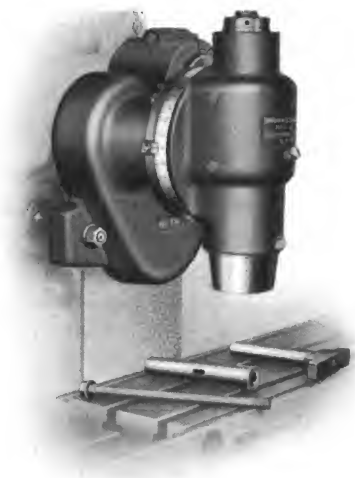


Fig. 29

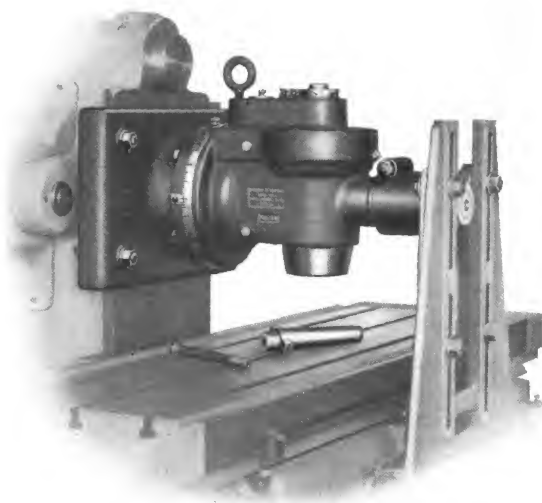


Fig. 30

means of a worm and wheel, and Fig. 30 illustrates one where spur gears are employed in addition to bevel gears.

Vertical Spindle Milling Attachments as built by us are divided into two classes, light and heavy. With one exception, all of our machines can be fitted with both light and heavy styles.

Fig. 28 shows a light attachment for the smaller sizes of machines, and Fig. 29 a heavy style for the same machines. Fig. 29 is also representative of a light style for the larger sizes of machines, the heavy style for these machines being shown in Fig. 30. The spindle nose of these attachments, except that shown in Fig. 28, is

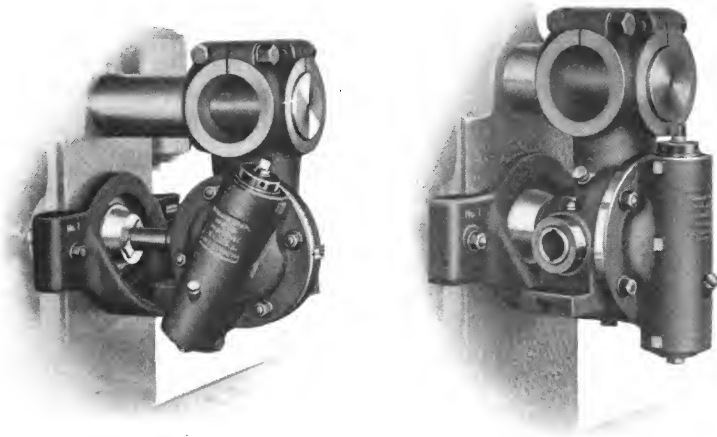


Fig. 31

tapered, hardened and ground; provided with taper hole, and has a recess in end to receive clutch on arbor or collets. The outer end of the heavy-style (Fig. 30) attachment is provided with a bearing that is stiffly supported by the arm braces.

Compound Vertical Spindle Milling Attachment. The Compound Vertical Spindle Milling Attachment, shown in Fig. 31 is particularly applicable to a large variety of milling, because it can be set in two planes. (See illustrations). It is especially advantageous when it is desired to set the spindle at an angle to the table, as in milling angular strips, table ways, etc., for with the spindle in this position, the full length of the table travel is available, and an ordinary end mill, instead of an angular cutter, can be used for milling the angle.

Universal Milling Attachment. Fig. 32 shows the Universal Milling Attachment, and as its name implies, it is fully universal in regard to setting the spindle. In addition to the large amount of work already mentioned in connection with the Vertical and Compound Vertical Attachments, this mechanism can be used for many other operations, because of the fact that the spindle can be set at any angle in both horizontal or vertical planes. It is clamped to the face of the column and the outer end is inserted in the arbor yoke to give additional stability.



Fig. 32

Horizontal Milling Attachment. We have mentioned the advantages to be derived from the use of vertical spindle milling attachments on horizontal spindle milling machines, and it is reasonable to suppose that to a certain extent, similar advantages are to be gained by the employment of a horizontal milling attachment on vertical spindle milling machines. An attachment of this kind is shown in Fig. 33. It is designed for use upon our No. 1 Vertical Spindle Machine, and with it such work as cutting spiral gears, racks, milling keyseats, etc., can be readily done. It is simple in construction and can be quickly attached to the machine.

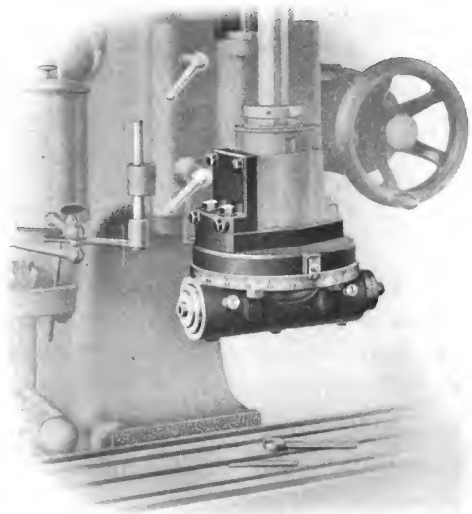


Fig. 33

Circular Milling Attachments. Circular Milling Attachments provide a means of economically doing such work as milling circles,

segments of circles, circular slots, etc., on plain and irregular shaped pieces. With the addition of one of these attachments, a vertical spindle milling machine is fully equipped for all varieties of straight

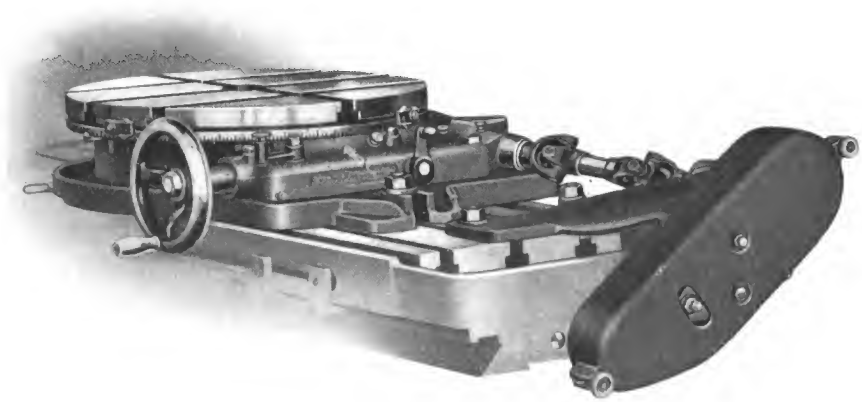


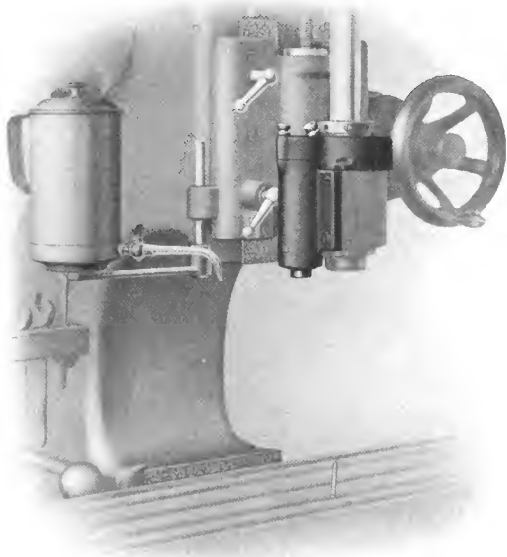
Fig. 34

and circular milling within its capacity. Likewise, one of these attachments used in connection with a vertical spindle attachment offers similar advantages on a horizontal spindle machine. Fig. 34 shows an attachment that can be used on our universal, plain and vertical spindle milling machines. The table is rotated by means of a worm and wheel, and can be fed automatically in either direction by power derived from the table feed screw. It can also be operated by hand when desired. For quick setting, the worm is thrown out of mesh and the table turned to any position. The table remains locked in position when the feed is stopped, but when straight milling or drilling is to be done, an additional clamp, operated by a lever at the side of the attachment, is employed to further insure its stability. The table is heavy and has a wide bearing surface; its circumference is graduated to degrees. The base is provided with an oil rim.



Fig. 35

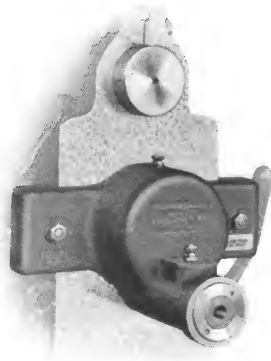
A Circular Milling and Dividing Attachment is shown in Fig. 35. This attachment

**Fig. 36**

the index finger on the front of the attachment is adjustable to allow readings to be taken from any convenient graduation, and an adjustable dial graduated to read to 5 minutes, is fixed to the worm shaft. An index table mounted on the front of the base gives the degrees required for setting the table to produce work with 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 16, 18, 20 and 24 sides. This is particularly valuable for use in connection with the slotting attachment.

High Speed Milling Attachment. Sometimes it is necessary in doing such work as milling keyways and slots, die making, etc., to use a small cutter, which should be run more rapidly than the fastest spindle speed available, otherwise it limits the production and is liable to be broken in feeding. In order to obtain correct speeds for these small mills, high speed milling attachments are employed. Fig. 36 shows one of these attachments for use on a vertical spindle milling machine, and Fig. 37 one designed for

is adapted for use upon vertical spindle machines, or horizontal spindle machines in connection with the vertical spindle milling and slotting attachments. It has no automatic feed. When used with the vertical spindle milling attachment, the machine is fitted for all varieties of straight, surface and circular milling within its capacity, and with the slotting attachment, for all kinds of slotted work, such as die making, making templates, splining keyways, etc. Its design embodies the same features as the ones just described, and, in addition,

**Fig. 37**

horizontal spindle machines. The construction in each case can be readily understood, as it consists of nothing other than a pair of gears for increasing the speed and an auxiliary spindle that drives the cutter.

Slotting Attachment. This attachment, shown in Fig. 38, is largely used in tool making, such as in forming box tools for screw machines, making templates, splining keyways, and work of a similar character. The working parts consist of a tool slide that is driven from the machine spindle by an adjustable crank that allows the stroke to be set for different lengths. The attachment can be set at any angle between 0 and 90°, either side of the centre line, the position being indicated by graduations on the circumference of the head. The tool is held in place by a clamp bolt, and a tool stop that swings over the top of tool shank makes it impossible for the tool to be pushed up.

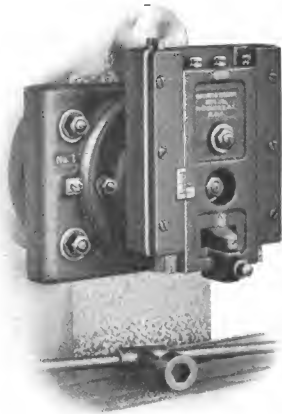


Fig. 38

Attachment for Cutting Short Leads. In cutting spirals with a spiral head, as the lead becomes shorter and a higher ratio of gearing becomes necessary, the stress upon the gears and mechanism becomes greater. For this reason, it is impractical to cut very short leads in this way. The attachment shown in Fig. 39 is designed particularly for use when it is desired to cut short leads.

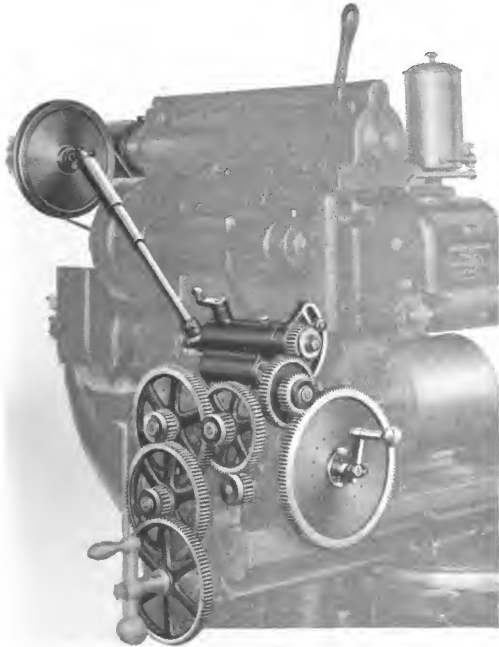
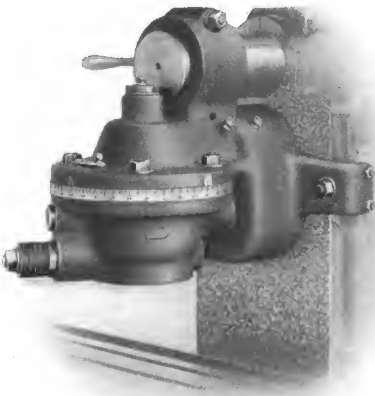


Fig. 39

It consists of a casting clamping over the dovetail of the spiral head carrying a swiveling gear plate and a short shaft which is driven from the rear of the machine spindle by a belt.

The work is rotated from the spindle independently of the feed screw, the latter being disconnected from the power feed mechanism.

**Fig. 40**

This attachment, shown in Fig. 40, is designed for the heavy class of spiral cutting in conjunction with the spiral head. The cutter is placed on the end of cutter spindle, allowing attachments to cover a large variety of work. In addition to cutting spirals, attachments can be used for cutting racks. The spindle can be set at any angle in a horizontal plane.

Rack Cutting Attachment. An attachment for cutting teeth in racks is shown in Fig. 41. It can also be used in connection with the spiral head for cutting worms, on Universal Milling Machines, as shown on page 173, and for other miscellaneous operations.

The cutter is mounted on the end of a hardened steel spindle that extends through the attachment case parallel to the table T slots. This spindle is powerfully and smoothly driven from the machine spindle by a train of hardened steel bevel and spur gears.

A vise, the construction of which can be plainly seen in the cut, is furnished as a part of the attachment.

When cutting racks, some convenient means of indexing to quickly and accurately space the teeth is

The regular index change gears are used on the swiveling gear plate to connect with the large index gear to give the work the proper speed of rotation. The lead is obtained as described on pages 58 to 63, allowing the rotation of the work to drive the table feed screw. Eighteen holes in the large index gear allow indexing when cutting multiple threads.

A rack cutting attachment or vertical spindle milling attachment is used to drive the cutter.

Spiral Milling Attachment.

**Fig. 41**

necessary. Fig. 42 shows an indexing attachment designed for this purpose. It consists of a bracket that is fastened in the table T slot at the left-hand end. The bracket carries a locking disk, together with change gears for gearing to the feed screw. To index any required spacing, change gears are selected that

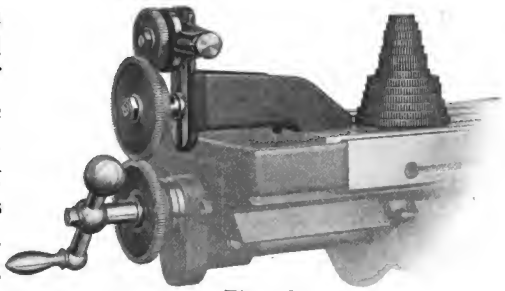


Fig. 42

will produce one or more whole turns of the locking disk. For each division the locking pin is withdrawn and the table advanced by the crank on the feed screw until the pin drops into the slot again, and locks the disk. This method of indexing is therefore much easier than relying upon a dial such as ordinarily used for the purpose.

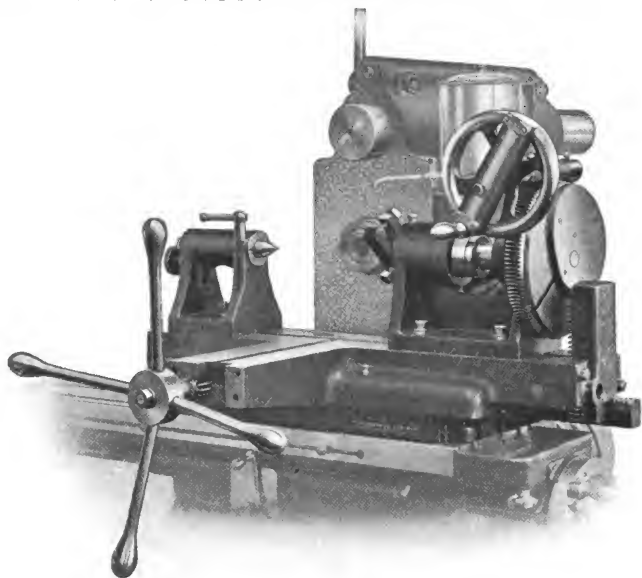
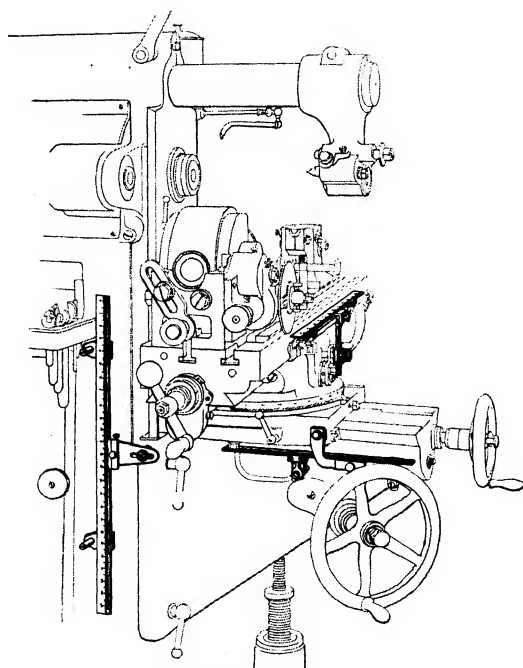
Tilting Table. A handy attachment, known as a Tilting Table, is shown in Fig. 43. It is designed primarily for use in connection with index centres when fluting taper reamers, taps, etc. In addition to this work, many other kinds of taper pieces can be accurately reproduced. Its general characteristics, the manner in which it is fastened to the table, and the way that it is elevated, are all clearly shown in the cut.



Fig. 43

Cam Cutting Attachment. The Cam Cutting Attachment, shown in Fig. 44, is used for cutting either Face, Peripheral or Cylindrical Cams from a flat former. The former is made from a disk about $\frac{1}{2}$ inch thick, on which the required outline is laid out. The disk is machined or filed to the required shape.

The table of the machine remains clamped in one position during cutting, and the necessary rotative and longitudinal movements are contained in the mechanism itself. The rotative movement is obtained by a worm driving a wheel fixed to the spindle of the attachment. The former is secured to the face of the worm wheel, and as the wheel revolves, the former depresses a sliding rack that

**Fig. 44****Fig. 45**

in turn drives a pinion geared to another rack in the sliding bed of the attachment, thus giving the necessary longitudinal movement. In the cut the former is shown in position on the face of the worm wheel.

The attachment is sometimes driven automatically by means of a round belt leading from a small jack-shaft to a three-step cone pulley fastened on the end of the worm shaft. The pulley is clutched to the worm so that either hand or automatic feed may be used by the simple movement of a lever. Illustrations of the use of this attachment are to be found in Chapter IX.

Scales and Verniers for Milling Machines. Scales and verniers are useful on such work as boring jigs, fixtures, or wherever extreme accuracy is required and it is necessary to make fine adjustments of the table. The scales are graduated to 40ths of an inch, and the verniers read to thousandths of an inch. A machine with all of the table adjustments fitted with scales and verniers is shown in Fig. 45.

Spring Chucks. Fig. 46 shows an unassembled spring chuck. This chuck is convenient for holding wire, small rods, straight shank drills, mills, etc. The collet holder is of steel, ground to fit the standard taper hole of the machine spindle, and has a hole its entire length. The front end is fitted to receive a spring collet, which is held in place by a cap nut that forces it against the taper seat and closes the chuck centrally. A nut is provided for withdrawing the collet holder from the spindle.

In addition to the attachments already mentioned in this chapter, there are many minor fixtures frequently used in milling operations. These are spoken of in connection with general notes on milling in Chapter VII.

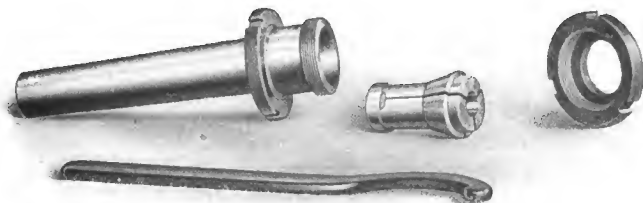
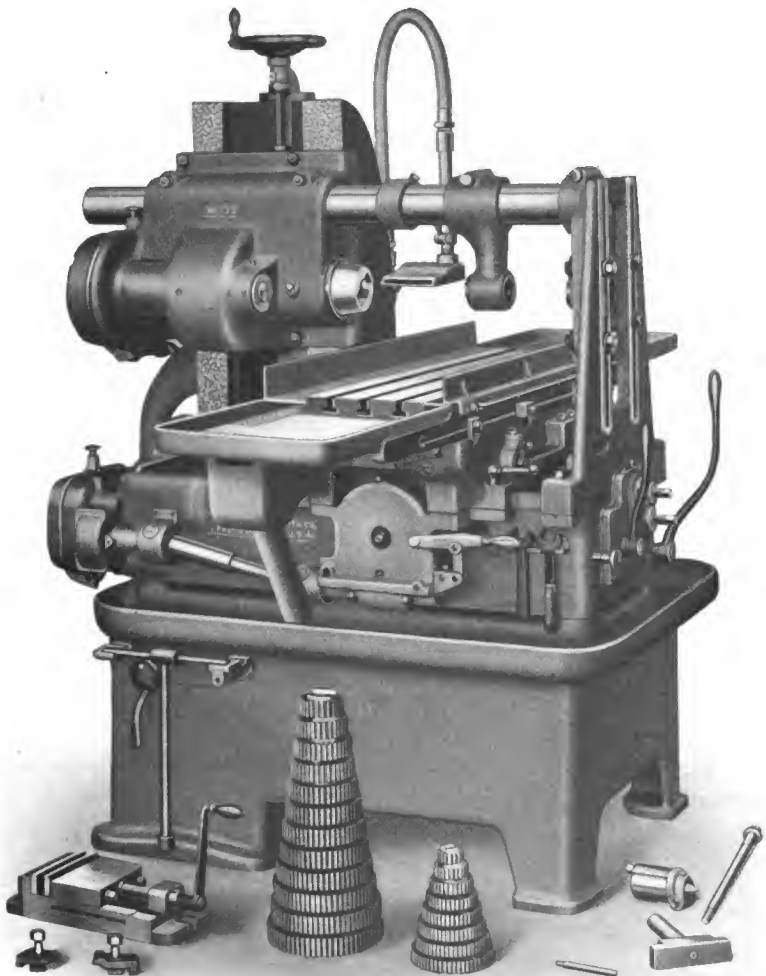


Fig. 46



Heavy Manufacturing Milling Machine

CHAPTER VI

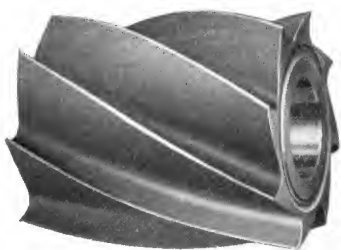
Cutters

The development of the manufacture of milling cutters, and a better understanding of their care and use, have resulted in a rapid growth in the number and variety of milling operations, and a corresponding increase in the sizes and varieties of cutters. It is evident, therefore, that the selection, care and use of milling cutters are points of utmost importance in attaining success in the process of milling. The failure to obtain commercial results may often be attributed to the fact that the wrong cutter has been used on a certain job, or even if the right cutter has been chosen, the work has not been done under the most favorable conditions.

Either the operator or the person in charge of the job should be proficient in the selection and care of cutters, and capable of determining the correct speeds and feeds at which to operate them. No theoretical knowledge of the design and manufacture of cutters is necessary to aid in this work, although a general understanding of these points is of material help. While we are able to give in the following pages such information as applies in common to the running of milling cutters, the most valuable experience will come only through actual work at the milling machine.

Carbon and High Speed Steel. Milling cutters are made from either of two varieties of steel, known as Carbon Steel and High Speed Steel. Those made from High Speed Steel can be subjected to more severe service than those made from Carbon Steel, and they are especially desirable where large amounts of metal must be removed rapidly, as in roughing out pieces of work. Cutter manufacturers can usually furnish all styles and sizes in either steel. No fixed rules can be given for their choice. The requirements of each job and experience in the use of cutters must determine which steel is more economical and will give the most satisfactory results.

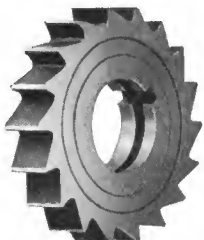
Plain Milling Cutter. This is a common type of cutter found in every shop, and may be described as a cylinder having teeth on the periphery only and producing a flat surface parallel to its axis. It is manufactured in a large variety of diameters and widths to meet



Coarse Tooth Plain Milling Cutter With Spiral Teeth



Coarse Tooth Milling Cutter with Spiral Nicked Teeth



Plain Milling Cutter



End Mill with Straight Teeth



End Mill with Spiral Teeth



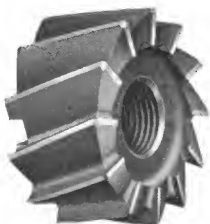
Coarse Tooth Side Milling Cutter



Coarse Tooth End Mill with Spiral Teeth



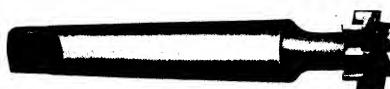
Centre Cut End Mill



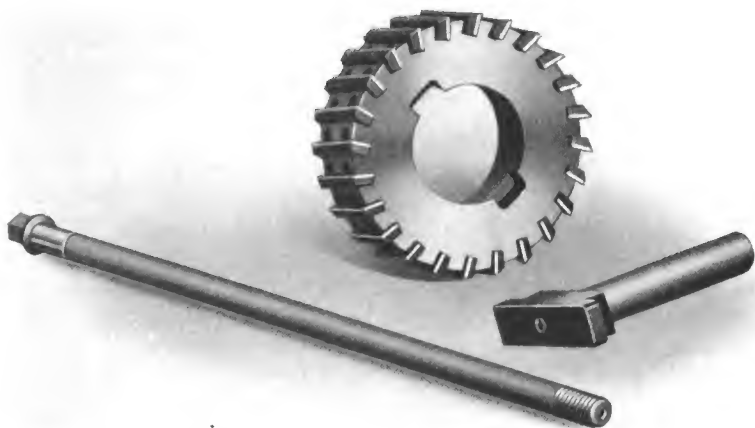
Coarse Tooth Shell End Mill with Spiral Teeth



Two-Lipped Slotting End Mill



T Slot Cutter



Inserted Tooth Face Milling Cutter with Cutter Driver and Drawing-In Bolt.*



Metal Slitting Saw



Convex and Concave Cutters with Teeth that can be sharpened without changing Form



Angular Cutters



Convex and Concave Cutters with Plain Milling Cutter Type of Teeth



Formed Cutter. Teeth can be sharpened without changing Contour



*Cutter Driver and Drawing-In Bolt furnished with machine

different requirements in slab milling, cutting keyways in shafts, etc. Saws for slitting metal and slotting screws are essentially plain milling cutters, although rarely regarded as such on account of their extreme thinness.

Plain milling cutters $\frac{3}{4}$ " or less in width are usually made with straight teeth, while those above that width have teeth of a spiral form. The object of the spiral is to give a shearing cut, reducing the stress upon the teeth, and preventing a distinct shock when each tooth engages the work as is the case with straight teeth. Consequently, a spiral tooth cutter on wide surfaces produces much smoother results

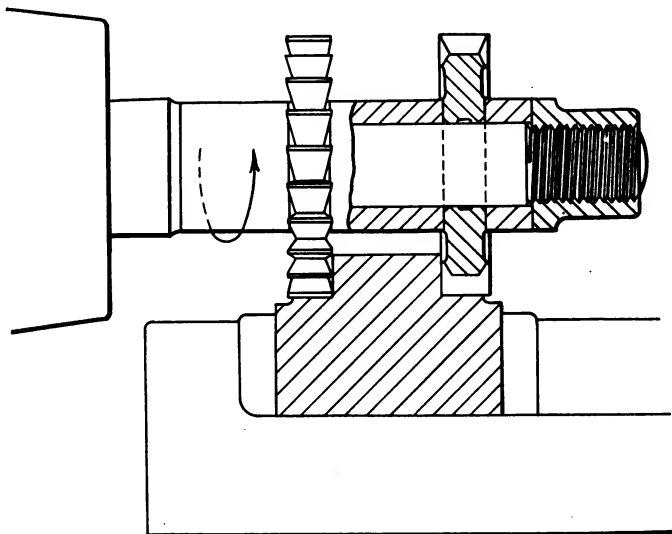


Fig. 47

than a straight tooth cutter. It requires less power to operate, and, in relieving the cutter of strain, the tendency to vibrate or chatter is reduced.

The teeth of cutters, especially those of a wide face, often have notches or nicks cut in them, the nicks following each other alternately. Cutters made in this manner can be run at coarser feeds than those with plain teeth, for the nicks break up the chips, and help to keep the cutters cool.

Side Milling Cutter. This type of cutter is like a plain milling cutter with the addition of teeth on both sides.

Side milling cutters are employed on a large variety of work, being used often in pairs with a space between, as shown in Fig. 47. When so used, they are known as "straddle mills." In work that has to be

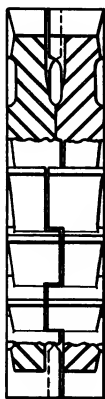


Fig. 48

milled on two parallel sides at once, as milling the heads of bolts, nuts, tongues, etc., straddle mills can be used most advantageously.

These cutters are also made with interlocking side teeth for milling slots to standard width. The teeth interlock, as shown in Fig. 48, and the standard width of the slot is maintained by packing washers between the cutters.

Face Milling Cutter. This cutter may be likened to a disk with teeth on the periphery and on one face. It is fastened at the end of the machine spindle, and the teeth on the flat face come in full contact with the work, while only a small length of the teeth on the periphery act on the piece. There are cutters of this type made which have no teeth on the periphery; an example of one is shown in Fig. 49.

End Mill. This type of cutter, like the face milling cutter, has teeth on the periphery and at the end.

End mills are used for a large variety of light milling operations, such as milling cuts on the periphery of pieces, cutting slots, and facing narrow surfaces. They are made in four distinct styles, the ordinary solid end mill, with either straight or spiral teeth, the end mill with centre cut, the slotting end mill with two lips, and the shell end mill with either straight or spiral teeth.

The ordinary solid end mill has its teeth cut on the same piece of steel that forms its shank; in reality, the space where the teeth are cut is only a continuation of the shank. The shell end mill has a hole through the centre so it can be mounted on the end of an arbor. This type should be used whenever

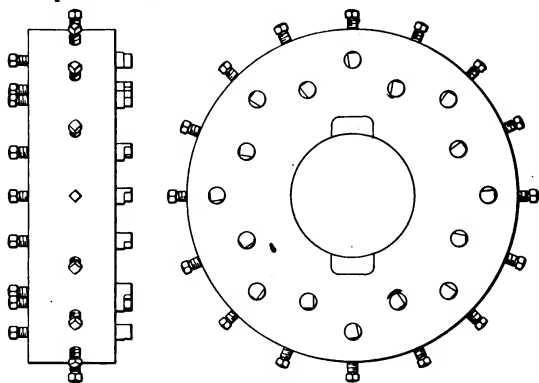


Fig. 49

possible, because it is cheaper to replace when worn out or broken than the solid mill. End mills with centre cut differ from the others in that the end teeth are designed to cut at the inner ends, while these teeth in ordinary end mills have no cutting edge at the centre. Centre

cut end mills are used for milling shallow recesses in a surface where there has been no hole previously bored for starting the cut, for milling squares on the ends of round shafts, and other similar work. This form of mill has fewer teeth, and is, therefore, better adapted to taking heavy cuts than the regular solid or shell end mills. Slotting end mills with two lips, or cutting edges, are especially adaptable to fast milling of deep slots from the solid where there has been no hole previously drilled for starting the cut. In fact, these mills embody both the principles of a drill and end mill. A depth of cut equal to one-half the diameter of the mill can usually be taken from solid stock. The best results are obtained by maintaining a high surface speed.

End mills with right-hand teeth usually have a left-hand spiral, and those with left-hand teeth have a right-hand spiral. By having the direction of spiral opposite to the faces of the teeth the thrust of the spiral tends to force the shank of the mill solidly into the spindle, although there is little danger of pulling out the mill when the teeth and spiral are of the same hand.

T Slot Cutter. The T slot cutter has teeth upon its periphery, and alternating teeth on the sides. The teeth are cut in the same piece of steel that forms the shank, as in the case of solid end mills. In making a T slot, an ordinary side milling cutter, or a two-lipped end mill, is first used, and then the wide groove at the bottom is formed with the T slot cutter.

Angular Cutters. Angular Cutters differ from the cutters described above in that the teeth are neither parallel nor perpendicular to the axis of the cutter, but are at some oblique angle. The cutter may have more than one angle.

These cutters can be employed on a variety of work, as cutting the edge of a piece to a required angle and milling teeth of cutters and reamers. Where the nature of the work is such, as in dovetailing a piece, that the cutter cannot be fastened to the arbor with a nut, the cutters are furnished with threaded holes, or made solid on a taper shank.

Formed Cutters. Formed Cutters constitute an important group, their cutting edge usually being an irregular outline. These cutters have teeth that are relieved so that they may be resharpened repeatedly or until the teeth are too slender to permit further grinding, without changing the original form as long as the teeth are ground radially on their faces. Illustrations of this type are shown on page 91, and

Figs. 50 and 51 show the extent to which they can be ground without changing the form of the teeth. Formed cutters with teeth relieved so that they may be ground on the faces without changing the contour, should be employed wherever the requirements of work demand that the original form of the cutter be maintained, as in manufacturing duplicate irregular pieces.



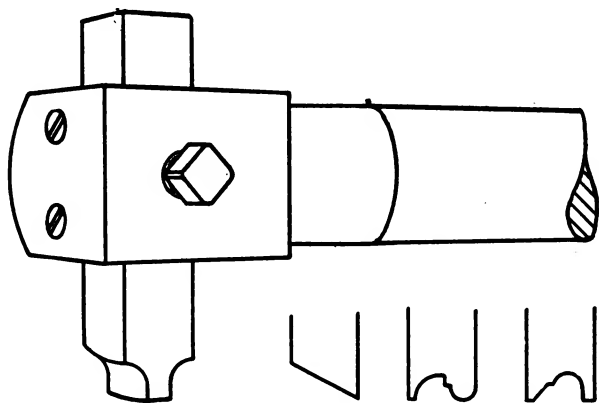


Fig. 52

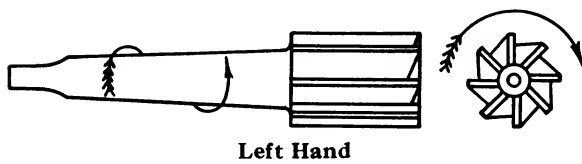
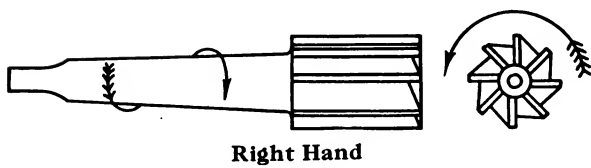


Fig. 53

for it is rarely used outside of the tool room or in experimental shops, but there it fills an important place. As it has only one cutting edge, it mills accurately to its own shape, but it does not cut so fast or wear as long as cutters with a number of teeth. It can be formed very exactly to any desired shape at a comparatively small expense, and thus may be used for many operations that otherwise would not bear the cost of special cutters, as, for example, when one or two teeth of special form are wanted in experimental work. The outlines of several possible shapes are shown in connection with the figure.

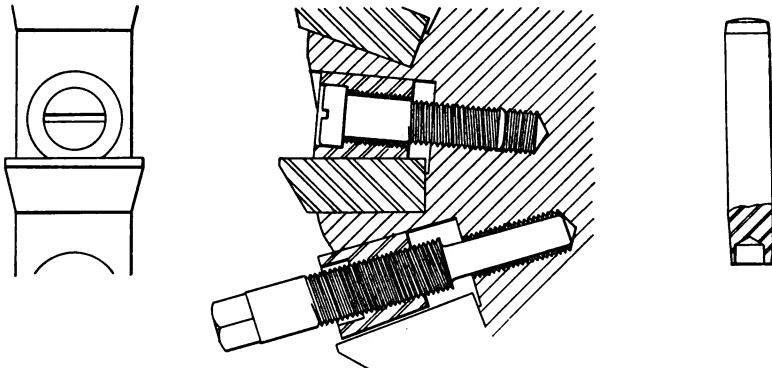


Fig. 54

Right and Left-Hand Cutters. Cutters or end mills with taper shanks and those which have end teeth, may be either right or left-hand, according to the direction in which the cutting edges of the teeth point. Taking an end mill for example, a right-hand mill is one which, held in the hand with the teeth away from you, presents the cutting edges of the teeth when revolved to the right or clock-wise. A left-hand mill is one that, similarly held, presents the cutting edges of its teeth when revolved to the left. Milling cutters having straight holes can be used either right or left-hand as desired.

Inserted Teeth. Plain milling cutters above 8 inches diameter, side milling cutters above 6 inches diameter, and face milling cutters, are usually made with inserted teeth. The body of the cutter is of steel, the teeth being held securely in place by various means. We employ a bushing and screw for this purpose, as shown in Fig. 54.

The introduction of cutters of this style has done more for heavy milling than any other improvement in the cutter line, for with them the heaviest and fastest cuts can be taken, and should any of the teeth become broken, it is not a question of a new cutter, but simply that

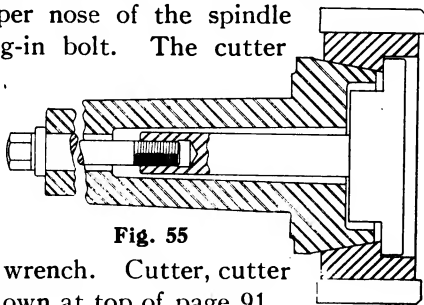
of replacing the broken teeth. The economy of this is of considerable importance to a shop.

If, for any reason, it becomes necessary to replace the full set of blades, or teeth, the new ones are clamped securely in position, and afterwards sharpened to correct any slight difference in height.

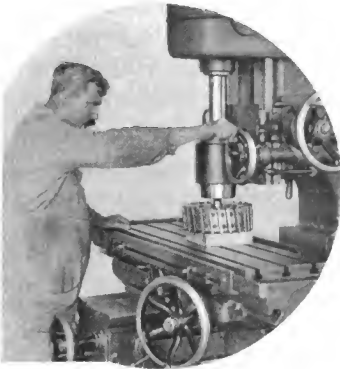
Teeth are released by removing the screw and inserting an extractor that threads into the bushing, and has a long end that reaches to the bottom of the hole in the cutter body. This extractor is shown in position in Fig. 54. As the extractor is turned by means of a wrench, the bushing is forced out and the tooth can then be removed.

Another type of inserted tooth face milling cutter that can be easily made in any shop is shown in Fig. 49. The teeth in this case are simply round pieces of steel inserted in holes made in the cast iron body of the cutter, and held in place by set screws. Sometimes two sets of teeth are put in these cutters. With this arrangement on heavy work that is not wider than the diameter of the inner circle of teeth, and which does not require close limits, the outer circle of teeth can be set to take a roughing cut, and the inner circle to take the finishing cut; thus work can be finished milled at one traverse of the table. Or if an exceptionally heavy roughing cut is to be taken off, the stress can be divided between the two circles of teeth.

Method of Holding Face Milling Cutters. Face Milling Cutters are drawn directly onto the taper nose of the spindle by a cutter driver and drawing-in bolt. The cutter driver fits into a slot in the face of the cutter and a recess in end of spindle. The shank of the cutter driver is threaded in the end to receive drawing-in bolt by which the cutter is drawn onto the spindle with the aid of a wrench. Cutter, cutter driver and drawing-in bolt are shown at top of page 91.



This method of attaching face milling cutters is simple and convenient and assures a positive drive. All possibility of "freezing" is eliminated, the removal of the cutter being as easily accomplished as its placement. Diagram of section through spindle and cutter, Fig. 55, shows cutter driver in place.

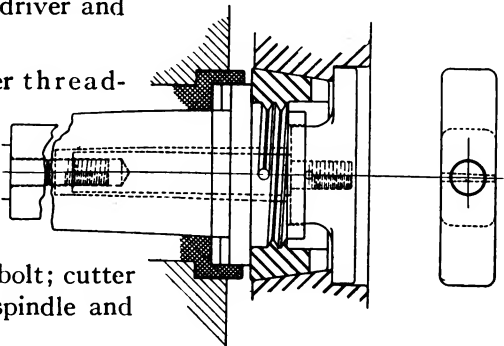
**Lowering Spindle into Cutter****Cutter in Place**

Face milling cutters are attached to spindle of Vertical Spindle Milling Machines as follows: Cutter is placed on table with cutter driver in place (wood block is used to avoid damage to table or cutter teeth). Spindle is lowered, the nose of spindle entering hole in cutter, and cutter driver entering recess in spindle, where it is securely held by drawing-in bolt.

An additional advantage is found in this cutter (page 91), in the increased available working space. There is no long hub, as the cutter is held close to the spindle. The body of each cutter is made of steel, and the blades of high speed steel.

On earlier machines, the spindle nose was threaded and a different style of face milling cutter was used. Face milling cutters designed for use on taper-nose spindles can be used on threaded-nose spindles by the use of an Adapter Outfit. This outfit consists of taper sleeve with threaded hole, cutter driver and drawing-in bolt.

The taper sleeve fits over threaded nose of spindle and, being of the same taper as hole in face milling cutter, allows cutter to be drawn onto it by use of the cutter driver and drawing-in bolt; cutter driver fitting recess in spindle and slot in cutter.

**Fig. 56**

Diagram, Fig. 56, shows sleeve and cutter driver in place.

Number of Teeth in Cutters. This subject has been discussed at some length by various writers in books and technical papers. Standard cutters have been found satisfactory for the majority of work, and practically indispensable on some work of the lighter class, but cutters having wide spaced teeth have a marked advantage over the standard type in their ability to remove a considerably greater quantity of metal in a given time without distressing the cutter or overloading the machine.

The free cutting action of these coarse tooth cutters is largely due to the fact that less cutting is actually required to remove a given amount of metal, each tooth taking a large, deep chip. This results in a considerable decrease in the tendency to slide over the surface and spring the cutter arbor. The rake and increased spiral of the teeth give a more nearly perfect shearing, rather than a pushing or dragging action. Accordingly there is less friction generated for a given cut, leaving the teeth much cooler and causing them to do considerably more work between grindings.

A marked advantage arising from the free cutting action is the consumption of less power, as might be expected from the fact that there is less friction and heating.

The wide spaces between the teeth allow the cutting edges to be well backed up, which was not always possible with closely spaced teeth. This increase in the strength of the teeth is much greater in proportion than the increase in work done by each tooth in removing the larger chips. Therefore the cutters are well prepared to handle deep and rapid cuts without danger of failing.

In developing the line of Brown & Sharpe Coarse Tooth Milling Cutters, particular attention has been given to the angle of rake and the lead of the spiral of the teeth. After a long series of practical experiments we have adopted a type with steep spiral and considerable angle of rake as the most economical and practical form, this type also being adapted to a large range of work which is not of the heavier class.

Angle of Tooth Face. Single point tools such as those used on the lathe and planer are usually given a slight rake; that is, the face of the tool is undercut a few degrees from a radial line. A similar practice is followed in setting the teeth in the body of large inserted tooth cutters so that they have a certain amount of rake. A smoother cut is gained and less power is consumed than would be with radial

teeth. For other cutters, however, it will be found that satisfactory results as to finish are gained with cutters whose tooth faces are perfectly radial. Practically all ordinary stock cutters with the above noted exception have radial teeth.

The clearance or angle of the teeth back of the cutting edge is also of considerable importance, and it will be taken up later in connection with sharpening cutters.

Diameter of Cutters. It is well to use cutters as small in diameter as the strength will admit. The reason is shown by Fig. 57. Suppose the piece I D C J E is to be cut from I J to D E. If the large mill A is used, it will strike the piece first at I when its centre is at K, and will finish its cut when the centre is at M. The line G shows how far the work must travel to cut off the stock I J D E. If the small mill B is used, however, it will strike the piece when its centre is at L and the work travels only the length of the line H.

Small mills are also preferable because they can do more and better work than larger ones, as there is less possibility of their chattering. Furthermore, they require less power and are not as expensive as large mills. The advantage of small mills has been illustrated in our own works, where a difference of $\frac{1}{2}$ an inch in the mills has made a difference of 10% in the cost of the work.

Temper of Cutters. A cutter is not necessarily too soft because it can be scratched with a file. On the other hand, care should be taken that cutters are not too hard or brittle, for trouble will quickly arise from the teeth breaking. If there is any question as to the temper of a cutter, it is better policy to consult with the cutter manufacturers than to attempt to correct it by drawing the temper, or re-tempering.

Gang Milling. Gang Milling receives its name from the fact that two or more cutters are placed together on an arbor and used at one time. Sometimes plain milling cutters are so combined in order to cover a wider space than the longest stock cutter. Again, formed cutters are used either with or without plain or side milling cutters. The use of formed cutters and plain milling cutters together should be avoided whenever possible, on account of the difficulty of maintaining relative diameters in sharpening the gang.

The value of gang milling is found in the fact that it reduces the cost of production and insures accurate duplication of parts, in that

several operations can be performed simultaneously, and with one setting.

It should be kept in mind that in this kind of milling, cutters of the largest diameter, or those that take the heaviest cuts, should, if possible, be used nearest the nose of the spindle, thereby reducing the strain on the arbor. If several of the cutters are plain milling cutters, it is well to use both right-hand and left-hand spirals in order to equalize the end thrust of the arbor. When, in gang milling, the cutters vary considerably in diameter, the inequality of the peripheral speeds may be overcome by having the cutters of large diameter made of high speed steel, and those of small diameter made of the ordinary carbon steel.

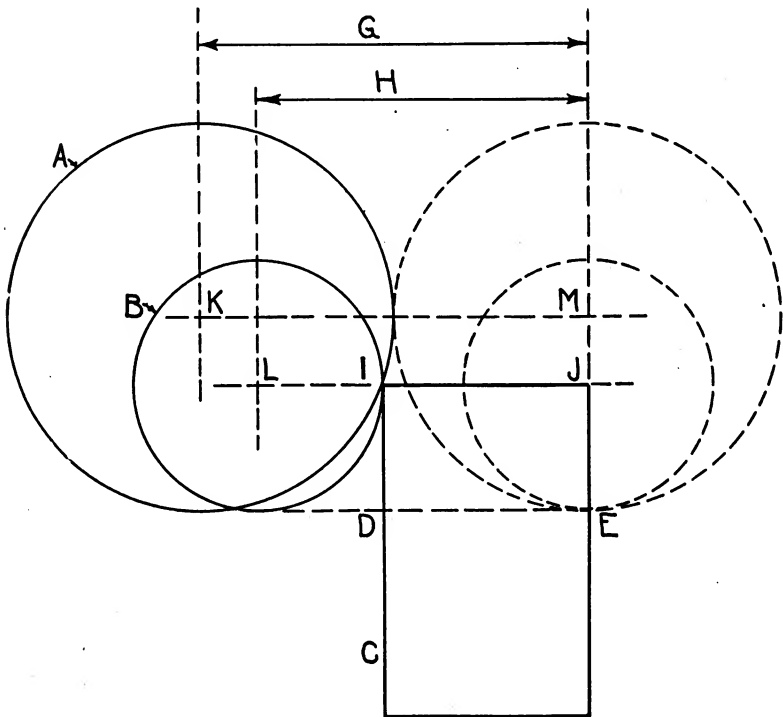


Fig. 57

Speeds and Feeds. Speeds and feeds are of extreme importance when considered in connection with the life and efficiency of a cutter and volume of output. Little can be said, however, in the matter of general rules to follow in determining correct speeds and feeds, owing to the different conditions that exist in different shops, and, in fact, in the same shop, where one set of rules will not always hold on like jobs. The amount of power and rigidity in different machines, kind of material, width and depth of cut, quality of finish required, and many other factors, all enter into the question, and prevent the establishing of any definite rules. Sometimes the speed must be reduced, yet the feed not changed, and vice versa; again both speed and feed must be reduced or increased, as the case may be. Often the rate of feed depends almost wholly upon the degree of accuracy and quality of finish required. In general, work of a delicate character, requiring an accurate finish, demands light cuts and fine feeds, and work of a heavy character, where the principal object is to remove metal rapidly, requires deep cuts and coarse feeds. On work that permits of heavy roughing cuts, the finishing cuts should usually be light. The feed, inasmuch as it governs the output of work, is of greater importance than the speed of a cutter, and it is generally a safe rule to follow, that the speed should be as fast as the cutter will stand, and the feed as coarse as is consistent with good work. Much must be left to the judgment of the operator as to the correct speed and feed to use for the work in hand, and many cases will require repeated experiments before the best results are obtained. When any difficulty is encountered in obtaining the right combination of speed and feed, it is well to seek the advice of the foreman in charge of the job, or that of a widely experienced milling machine operator.

The following surface speeds will serve to give an idea, or basis, to work from. They may be varied slightly to suit the requirements of the work in hand. Using carbon steel cutters: For brass, 80 feet to 100 feet per minute; for cast iron, 40 feet to 60 feet per minute; for machinery steel, 30 feet to 40 feet per minute; and for annealed tool steel, 20 feet to 30 feet per minute, have been found satisfactory. With high speed steel cutters for the same materials, the following speeds are advocated: For brass, 150 feet to 200 feet per minute; for cast iron, 80 feet to 100 feet per minute; for machinery steel, 80 feet to 100 feet per minute; and for annealed tool steel, 60 feet to 80 feet per minute.

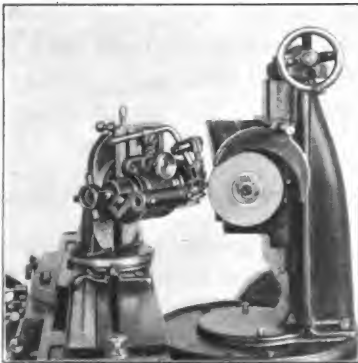
Useful tables for determining the number of revolutions per minute to obtain the more common surface speeds of cutters of different diameters, will be found on pages 327 and 328.

Sharpening Cutters. The importance of keeping all kinds of milling cutters well sharpened must not be overlooked. It might be supposed upon first thought that better economy in cutter wear would be gained by regrinding no oftener than positively necessary. This is not the case, however, as experience has shown that a dull cutter wears more rapidly than a sharp one, and consequently one that is kept in good condition by frequent regrinding will invariably outlast one that is not so cared for. Besides, a dull cutter not only consumes more power, but cannot be operated as rapidly or take as heavy cuts as a sharp one, and the quality of the work is never as good. Too frequently in shops today, the efficiency of milling machines is impaired by the use of dull cutters, for no other reason than carelessness and negligence on the part of the operator. Milling is never a complete success where such conditions exist, and with the improved grinding machines and convenient means of removing and replacing cutters, there is no reason for limiting the capabilities of a machine by using dull cutters. Grinding a cutter takes only a short time, and the good results that are obtained, together with the economy assured, more than compensate for the time expended in grinding. Whenever possible, it is a good plan to have two sets of cutters, so that one set can be reground while the other is in use; the milling machine then need only be stopped long enough to change the cutters.

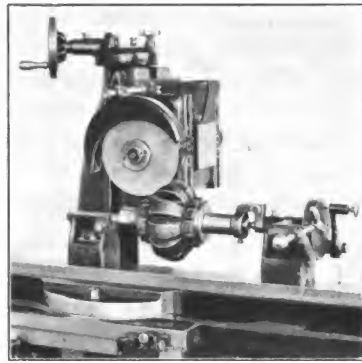
Plain milling cutters, side milling cutters, end mills, etc., are sharpened upon the tops of the teeth, while formed cutters of all kinds are sharpened upon the faces of the teeth. Modern cutter grinding machines are necessary where many cutters are employed, and are advantageous, even where there are only a few cutters used, for it is nearly impossible to properly resharpen cutters, except with a machine especially designed for that purpose. We illustrate at the back of the book the cutter grinding machines we build that are very suitable for use in connection with milling machines.

It is impossible to treat in detail the many points about resharpening cutters without going to great length, but we issue a book and booklet* devoted exclusively to the subject, one of which is furnished with each of the machines mentioned above.

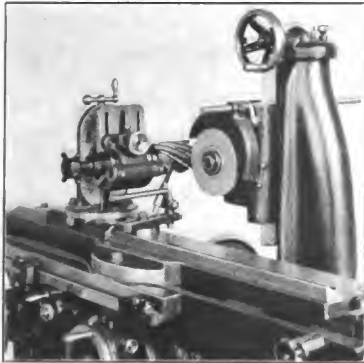
* "Construction and Use of No. 13 Universal and Tool Grinding Machine," and "Construction and Use of No. 2 Cutter Grinding Machine and No. 3 Universal Cutter and Reamer Grinder."



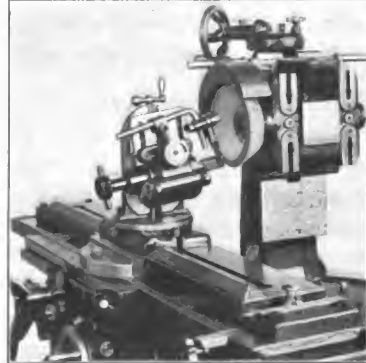
**Beveling the Corners of a Coarse
Tooth Shell End Mill**



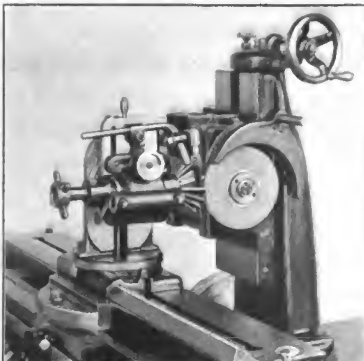
**Grinding a Formed Cutter
on Index Centres**



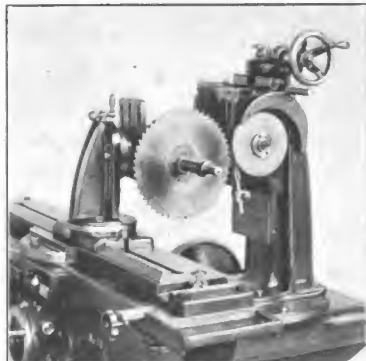
**Re-Nicking a Coarse Tooth
Milling Cutter**



**Grinding the End Teeth of a
Coarse Tooth End Mill**



**Grinding the Teeth of an
Angular Cutter**



**Grinding the Teeth of a
Small Saw**

Clearance on Cutters. The clearance or relief of milling cutters is the amount of material removed from the top of the teeth back of the cutting edge to permit the teeth to clear the stock and not scrape over it after the cutting edge has done its work. On formed cutters, the clearance does not have to be considered in resharpener. This is because the teeth are so formed that when ground on the faces, the clearance remains the same.

The angle of clearance depends upon the diameter of the cutters, and must be greater for small cutters than for larger ones. The clearance on the teeth of plain milling cutters should be 4° for cutters over 3 inches in diameter, and 6° for those under 3 inches diameter. The clearance of the end teeth of end mills should be about 2° , and it is well to have the teeth a little hollowing, making them .001 or .002 inch lower near the centre than at the outside, so that the inner ends of the teeth will not drag on the work. This can be done by setting the swivel on the cutter grinder slightly away from 90° .

Vibration of Cutters. If the clearance of a cutter is too great, vibrations are likely to occur in operation, and this should be corrected by regrinding the teeth. "Chattering" is a serious drawback to successful milling, as it impairs the quality of the work, limits the capacity and injures a machine, and reduces the life and efficiency of a cutter. While it is impossible in many cases to eliminate it, every precaution should be taken to reduce it to a minimum.

CHAPTER VII

General Notes on Milling, together with Typical Milling Operations

Milling, as we have already explained, is a process that cannot be governed by any fixed set of rules, but there are a few general instructions which, if carefully followed, will enable the machine to be more efficiently operated and largely influence the success that is attained. These we have collected in this chapter, and, in addition, show illustrations of a number of common milling operations to give an idea of how various and widely different jobs can be set up.

GENERAL NOTES ON MILLING

Pickling Castings and Forgings. Due to the rapid cooling or chilling of the outside of castings and forgings, a tough, hard skin, or scale forms, that is very destructive to the cutting edges of the teeth of milling cutters. There is also considerable of the moulding sand left on castings, and this is likewise harmful to the cutting edges. The sand can be removed and scale softened to some degree by the process of pickling, and it is essential that this be done preparatory to milling. Castings are usually pickled in the foundry, but it is well to make sure that this has been done before attempting to mill them. It is also an advantage in some cases to have castings rattled after being pickled. Where they are small, and are to be finished rapidly, they should be annealed.

For pickling castings, a solution of oil of vitriol, or sulphuric acid, reduced with water to a specific gravity of 25° (Beaume hydrometer) is recommended. The castings should be stacked on a bench over a vat containing the solution, and the solution poured over them.

Castings should never be immersed in the pickling bath if they are to be painted, because the iron is more or less porous, and the acid that is absorbed in pickling will work out after the pieces are finished, causing the paint to flake off. Furthermore, the pickle works better when it is poured over the castings and then allowed to dry off before another application of the solution.

The time required for the process is usually about a day, and the solution should be poured over the castings from four to five times.

Forgings may be pickled by immersing in a solution of sulphuric acid and water of 30° specific gravity (Beaume hydrometer) for a period of from 3 to 12 hours, according to hardness of scale.

When either castings or forgings are pickled, they should be thoroughly washed off with hot water, as this will wash out sand and remove the acid better than cold water. The water may be conveniently heated for this purpose by injecting steam into the cold water pipe.

Cutter Close to End of Spindle. In all milling operations, especially the heavier ones, care should be taken to have milling cutters as near the nose of the spindle as practicable. This will reduce to a minimum any possible vibration and spring of the arbor. It also brings the table close to the face of the column and ensures additional rigidity. Other valuable points about cutters have been taken up in Chapter VI, and it may be well to review these previous to starting to operate a machine.

Fastening Cutter on Arbor. See that the ends of the collars and washers are clean, for particles of dirt or chips between them will cause the arbor to be sprung when the nut is tightened. Small cutters can be held securely by the mere clamping effect of the collars on each side when the nut is tightened, but medium and large cutters should always be keyed to the arbor to prevent slipping.

Manner of Driving and Supporting Arbors. Milling machine arbors are driven in several different ways, some of which are shown in Fig. 58. In A, the arbor has a tenon at the small end of the taper that fits a slot at the end of the taper hole in spindle, thus giving a positive drive. The method of driving arbors B and C is similar to that of driving face milling cutters, described on page 98. The arbor is provided with a clutch, and has threaded hole in end of shank; the clutch fits into recess in end of spindle, and the arbor is drawn into place and held securely by the drawing-in bolt, (see Fig. 58.) The method of driving collets is the same as that of arbors.

All milling machines are equipped with some support for the outer end of the cutter arbor. The adjustable centre shown at A is one form that is used for lighter classes, or work where an arbor with a flat tenon is employed. The centre serves to support the outer end of the arbor and helps to keep the flat tenon in place in the slot in the spindle. Another form of support is shown at B. This support is a bronze bushing mounted in the arm that extends down from the overhanging arm, and is used where an arbor with clutch drive is employed. An

example of the use of arm braces that extend from the knee to the overhanging arm and carry the bronze bushing for the outer end of the arbor is shown at C. These braces firmly tie the knee and overhanging arm together, and give a stiff support for the arbor. They should be used whenever the character of the work is heavy. This illustration also shows the use of an arbor yoke for stiffening the arbor between the cutters. This yoke should be used to bring a bearing either between or as near to the cutters as possible.

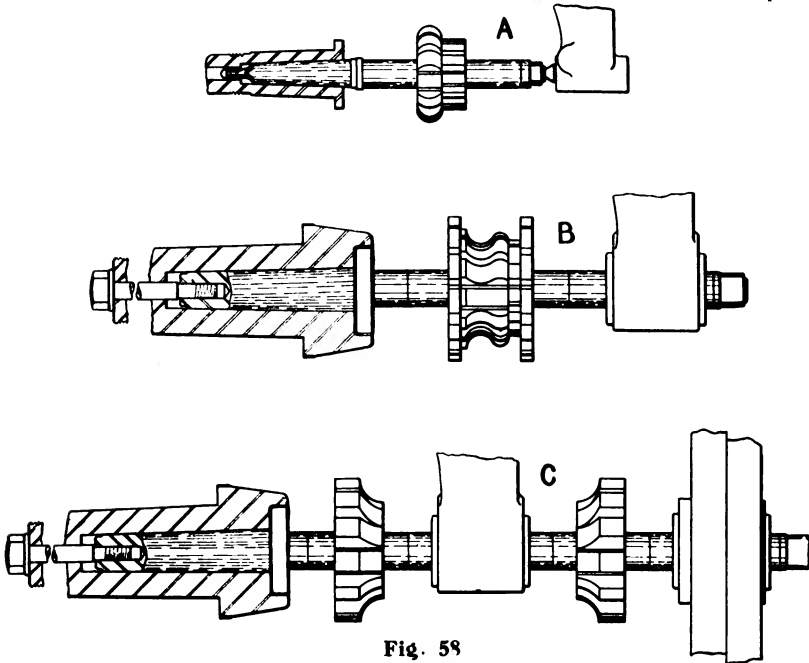
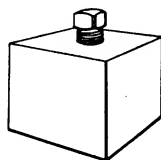
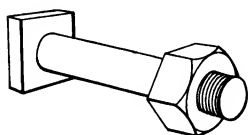
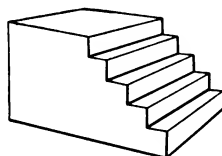
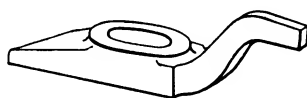
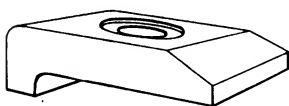
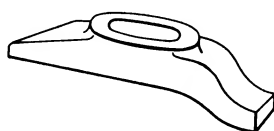
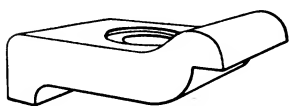
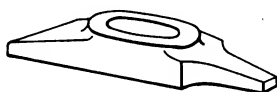
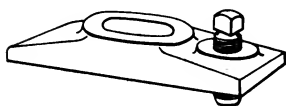
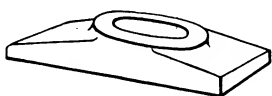


Fig. 58

Before tightening or loosening the arbor nut, when putting on or removing cutters, be sure the arbor support is in position, so that a bearing is provided near the nut, otherwise the arbor is liable to spring.

Clamping Work. An operator should pay particular attention to clamping work on a milling machine, for the success of milling is more dependent on this than one would realize at first thought. It is an easy matter to place clamps on some work in such positions that the piece is sprung, consequently when the clamps are loosened and the piece resumes its natural shape, the milled surface is found inaccurate. Again, faulty clamping results in work becoming loosened during operation, and not only impairs the accuracy of the piece, but many



times damages the cutters and machine. It is very essential, therefore, that work be clamped solidly, but in such a manner that it is not sprung.

An assortment of clamps or straps, together with jacks, a shim, step block and clamping bolt, are shown on the opposite page. These accessories form an important part of the equipment of a milling machine, and are needed where a variety of work is done. Several sets of each style of strap, and different sizes of step blocks and clamping bolts should always be at hand for use on work of varied shapes.

Whenever clamping a piece to the table, the straps should be placed squarely across, so as to have a full bearing at each end and, if possible, at points where the work extends down to the table beneath the strap. If it is necessary to place a strap over an overhanging part, such as on the piece of work shown on the next page, some support should be put between the overhanging part and the table, otherwise this part is liable to be sprung or broken off.

Another point in connection with clamping such work is the position of the clamping bolt. It should always be placed as near the work as the slot in the strap or other conditions will permit, for in this position it will exert the greatest pressure on the work and will not require setting up so tightly.

When milling work held in a jig or fixture, it is advisable to have the thrust of the cutter taken against the solid support, not against the removable member, for in this case there is more tendency toward vibrations that might loosen the clamping nuts.

When duplicate pieces are milled, using a fixture, care should be taken to clean the bearing points each time before putting

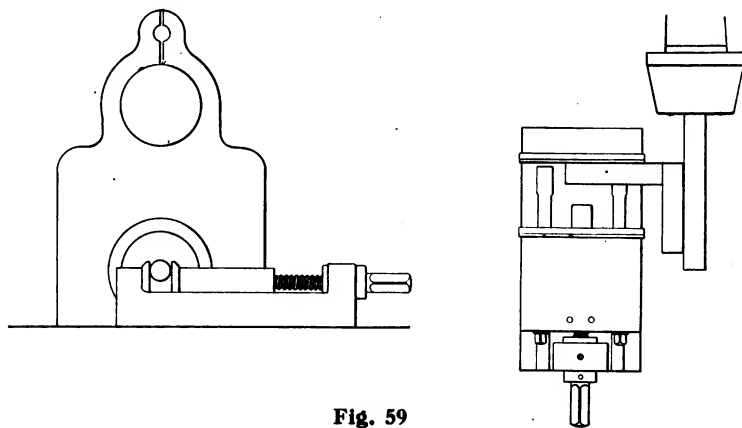
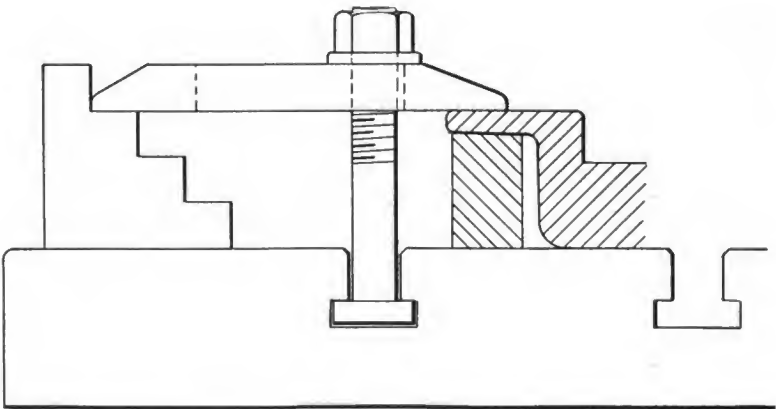
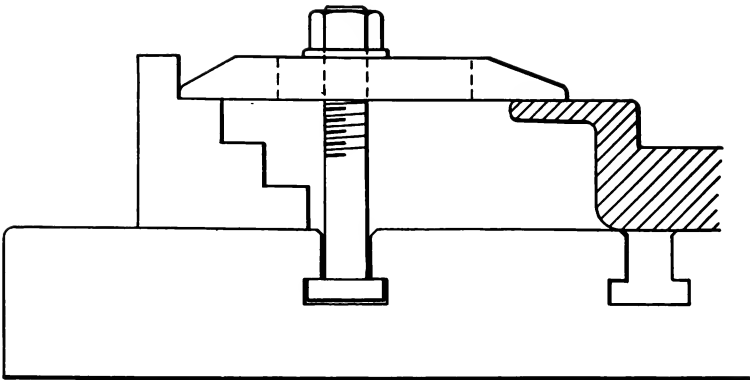


Fig. 59



Right



Wrong

a new piece of work in place. A narrow, stiff hair-bristle brush is good for this purpose when milling cast iron, but one with wire bristles is better for cleaning out steel or wrought iron chips. It is well to clamp a piece lightly, then tamp it down at all bearing points with a hammer; after which it can be solidly fastened.

Aside from these few general instructions on placing and clamping work, little can be said, because the shape of a piece of work alone determines how it may be best fastened. But a study of the methods of clamping shown in the examples of work in this and succeeding chapters will be of great value to the reader.

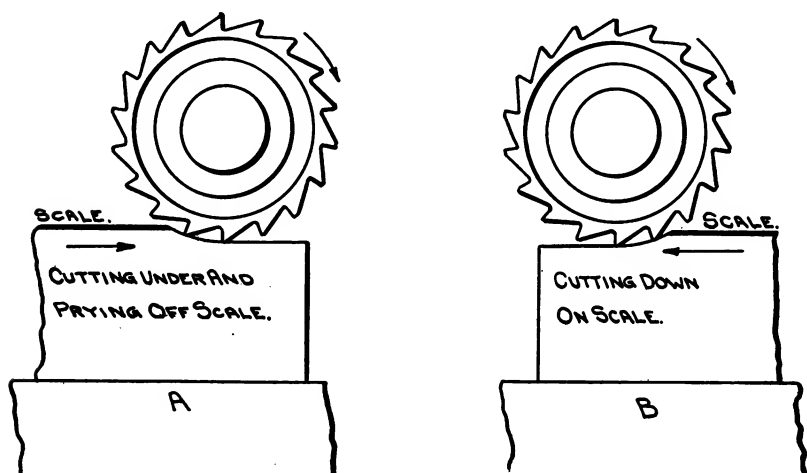


Fig. 60

Setting Vise. Light work is usually held in a vise, as it is more convenient than any other method of fastening it to the table. To set a vise with plain base so that its jaws are parallel to the spindle, place an arbor in the spindle and then bring the vise jaws up to the arbor. (See Fig. 59). It can be set at right angles with the spindle by a square placed against the arbor and the jaws. The front of the table of the machine can also be used in setting the vise.

Swivel vises can be set by aid of the graduations on their base.

Direction to Move Work Under Cutter. Whenever possible, it is advantageous to feed the work in the opposite direction from that in which the cutter runs. (See A, Fig. 60). Then the cutter cannot draw the work in as it is liable to do when the table moves in the direction indicated at B. Moreover, when the piece moves as shown at A, the

cutter teeth are first brought into contact with the softer metal, and as the scale on the surface is reached, it is pried or broken off.

On the other hand, in milling deep slots, or in cutting off stock with a thin cutter, or saw, it is sometimes better to move the work with the cutter, as the cutter is then less likely to crowd sidewise and make a crooked slot.

When the work is moving with the cutter, the table gib screws must be set up rather hard, for the teeth of the cutter tend to draw the work in, and if there is any lost motion in the table, the teeth may catch and injure the cutter or work. A counter-weight to hold back the table is excellent in such milling.

With vertical spindle milling machines, when a cutter is working on a flat surface, it does not matter which way the table is fed, but if the cutter is milling a side of a casting, as well as a flat surface, the table should be fed in the opposite direction to that in which the cutter revolves, for the reasons already mentioned.

Limits in Milling to Size. The limit for error in size to which work should be milled depends entirely upon the character of the job. With some work, a limit of one-hundredth of an inch is plenty good enough, while many other pieces must be finished to within one-thousandth of an inch of being exactly parallel or straight, as the case may be.

In milling to a given thickness or size, the most accurate results are ordinarily obtained by straddle mills or side milling cutters; for when only one side is milled at a time, and the piece has to be changed from one side to the other, it is hardly practicable to work to a smaller limit than two-thousandths of an inch. Side milling frequently requires more attention to keep the work smooth than ordinary surface milling.

Very accurate milling may be done and excellent surfaces obtained by small end mills running at high speeds.

In all cases where roughing and finishing cuts are to be taken on work, and precision is required, it is best to first remove most of the stock with a coarse feed, leaving enough for a light finishing cut. At a second operation, finish at a higher speed with a feed that will give the required surface.

Some light work will spring when the scale and a thickness of the metal are removed by the roughing cut. It is, therefore, advisable to loosen the holding clamps and permit the piece to assume a natural form before taking the finishing cut; otherwise, whatever inaccuracy

that might result from the foregoing cause would be present in the finished work.

Remove Backlash or Lost Motion from Feed Screws. Backlash or lost motion is apt to be present in the feed screws and nuts of any machine, especially in those that have been in use some time. To obviate errors in making fine adjustments, the operator should be very careful to eliminate all backlash before setting to the graduations on the feed screw dials. This may be done by turning the hand-wheel a quarter or half turn in the opposite direction to that in which the adjustment is to be made, and then bringing the wheel back to the point from which adjustment is to be made.

Use of Oil or Other Lubricant. Lubricant is used in milling to obtain smoother work, to keep the cutters cool so that the teeth will retain their cutting edges longer, and, where the nature of the work requires, to wash the chips from the work or from the teeth of the cutters. Oil is generally used in milling steel, wrought iron, malleable iron or tough bronze, where a smooth finish is desired. A soda water mixture can also be used to good advantage on these materials.

For very light cuts, oil should be applied to the cutter with a brush; for heavier cuts, it should be allowed to drip freely upon the cutter from a can, and on the heaviest cuts, a large supply of lubricant should be supplied by means of a pump, which can be affixed to the machine.

A good quality of lard oil is generally used, but any animal or fish oils may be employed. An excellent soda water lubricant that is less expensive and cleaner to use than oil, can be made by mixing together and boiling for one-half hour, $\frac{1}{4}$ lb. sal soda, $\frac{1}{2}$ pint lard oil, $\frac{1}{2}$ pint soft soap and water enough to make ten quarts.

Cutting Cast Iron. In cutting cast iron, lubricant is seldom used, as cutters do not usually heat very much, and the chips are so fine that the use of a lubricant results in a sticky mass that clogs the teeth of the cutter, and is difficult to clean from the work and machine.

Compressed air can be used to some advantage on cast iron, and will serve to keep the cutters cool and free from chips. In using compressed air care should be exercised not to have too much pressure, as it will scatter the dust and chips, which will fill bearings and cause trouble.

Collars and Washers for Arbors. Collars sent with milling arbors are not always the right thickness to bring cutters into the desired

position. In these cases, washers should be employed. The following thicknesses are convenient: .001", .002", .004", .008", .016", and .032", as these give all steps from .001" to .032".

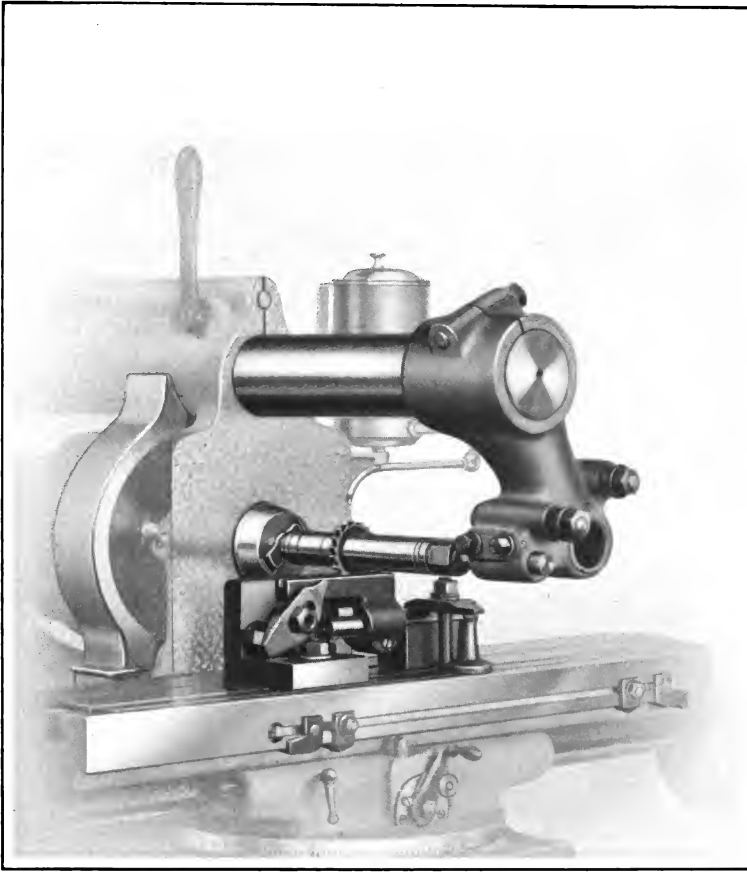
The collars should be of uniform thickness, otherwise they are likely to spring an arbor when they are clamped up.

Lead or Brass Hammer, and Brass Bar. Lead or brass hammers are useful to drive arbors or collets into the spindle, and seat work in a jig or vise. A steel hammer should not be used for these purposes, as it will mar pieces. Short lengths of gas piping with a cap on the protruding end make good handles for lead hammers.

A bar of brass or copper, $\frac{3}{4}$ inch in diameter and five or six inches long, will also be found useful to place against end mills, or the end of small collets after the mills are in place. In this way the driving is often more conveniently done, and any hammer may be used.

TYPICAL MILLING OPERATIONS

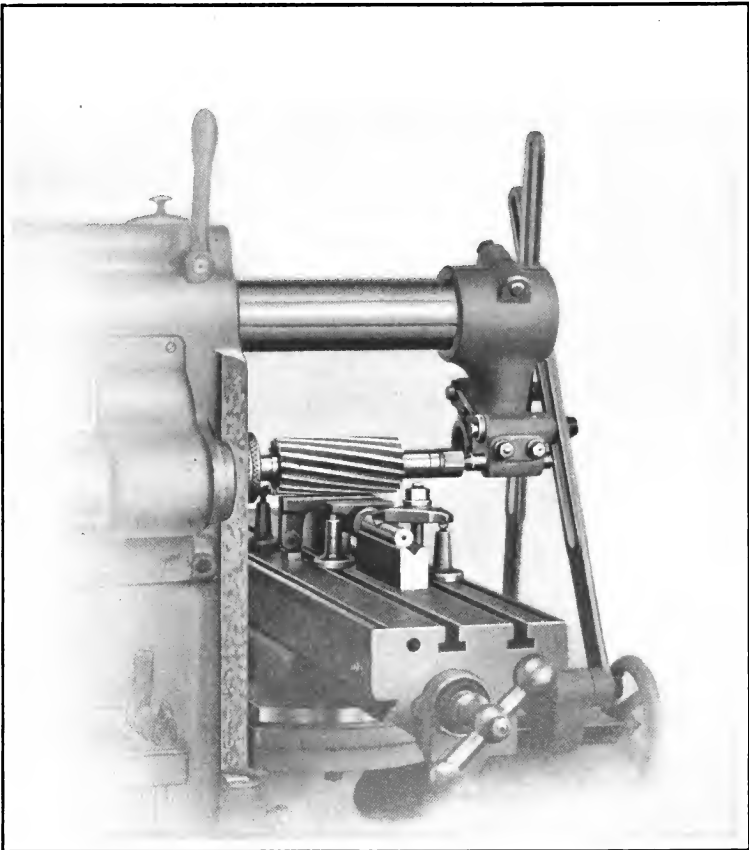
In the illustrations of milling operations given upon the following pages, it should be understood that we have not attempted in every case to show how a job should be rigged up for commercial manufacturing, as special fixtures designed solely for certain operations are then employed. Our object is simply to show the novice how any number of jobs he is likely to meet with daily can be best set up. If it is a question of performing the same operation continuously, special fixtures, by use of which the work can be more conveniently and quickly handled, can be designed.



Milling a Groove in a Machine Part

In the illustration above, the work is of cast iron, in which a groove $\frac{1}{4}$ inch wide is to be milled parallel with the hole. The piece is held on an arbor mounted in a V block and clamped to the surface of the table. Its overhanging end rests on a set screw tapped into the base of a knee bolted to the table, and a bolt and strap clamp the end firmly to the side of the knee.

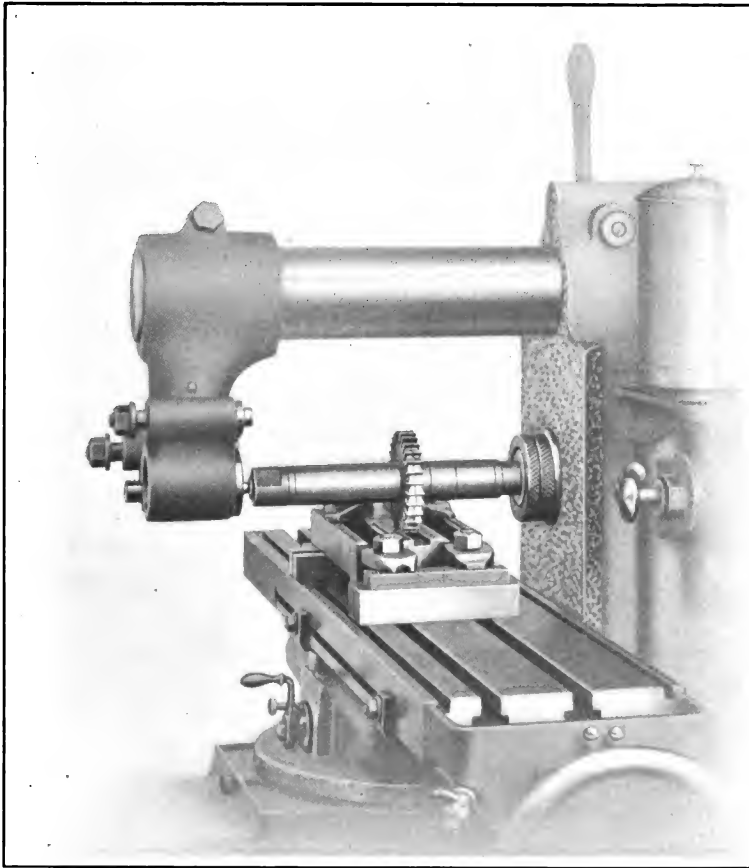
A plain milling cutter, $\frac{1}{4}$ inch face, 2 inches diameter, is used, and the table is fed longitudinally.



Surfacing Top of a Bracket

This is a simple and common milling operation. The cast iron bracket is supported on an arbor that rests on V blocks at each end. Bolts and straps hold the arbor and V blocks in place, and the projecting portions of the bracket are supported by small jack screws. As the full width of surface is milled at one cut, the arm braces are used to support the arbor. Also, the cutter is placed as near the nose of the spindle as the work allows.

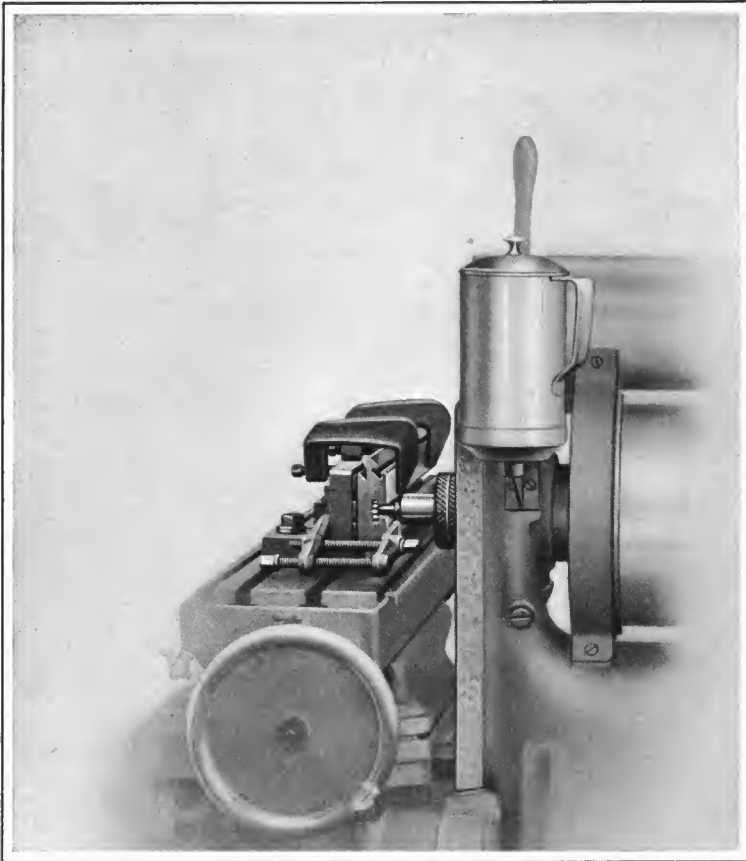
Because of width of cut, a plain milling cutter with spiral teeth 6 inch face and $2\frac{3}{4}$ inch diameter, is used.



Cutting Slot in Vise Casting

The operation shown on this page is that of milling a slot on the bottom of the base casting of a milling machine vise, such as that shown in Fig. 18. The casting is clamped directly to the table and the farther end is supported on parallels.

An interlocking side milling cutter, $\frac{3}{4}$ " wide, is used, and the table is fed longitudinally. The value of the interlocking cutter is apparent here, for it is essential that the width of slot milled be maintained after the cutters have been ground. This is accomplished by packing thin washers between the two parts of the cutter.

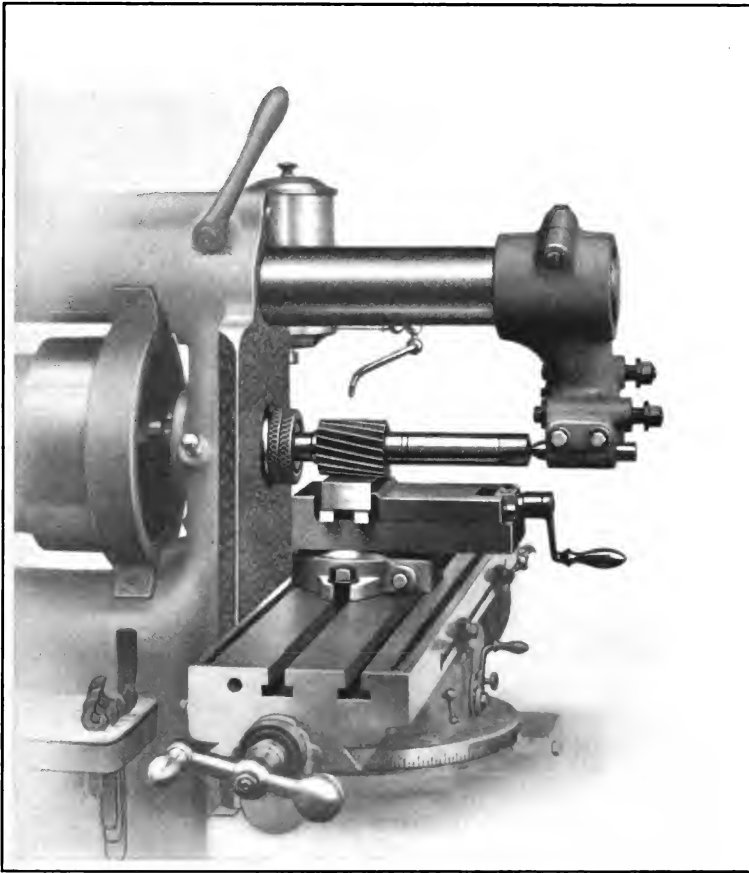


Milling T Slot in a Table

Milling a T slot consists, as we have already explained in Chapter VI, of two separate operations. A straight slot is first milled to the full depth with a plain milling cutter, which is $\frac{1}{2}$ " wide in this case. The work is then turned on edge and clamped to knees so that it is square with the spindle. It is leveled by means of a surface gauge or height gauge, measuring from the straight slot to the top of the table.

A standard $\frac{1}{2}$ " T slot cutter is used, and the table is fed longitudinally in the path of the straight slot.

This job can be done to good advantage on a vertical spindle machine, or with a vertical spindle attachment, using a two-lipped end mill and T slot cutter.

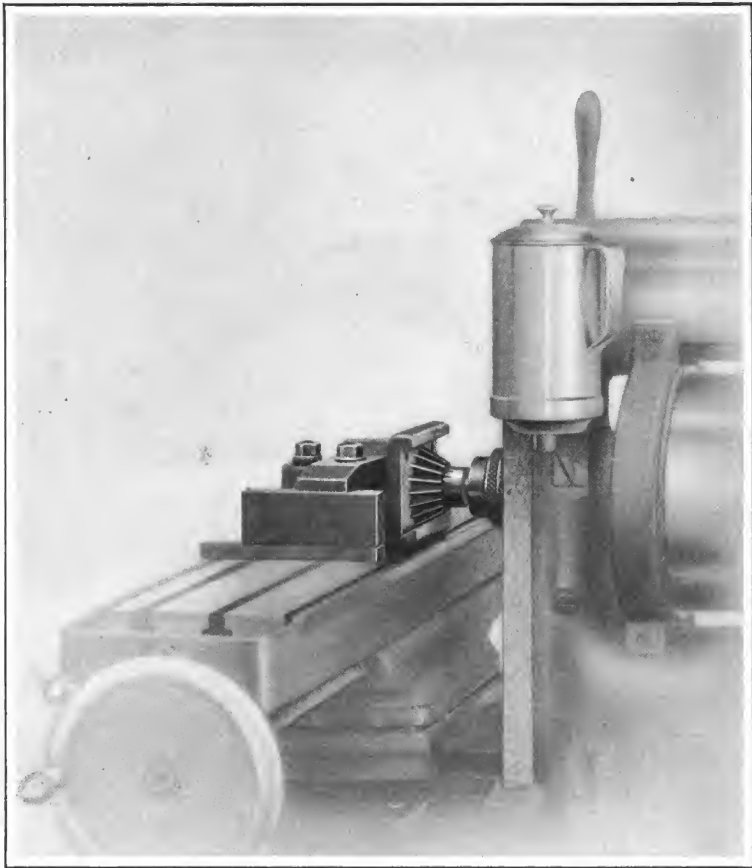


Milling Steel Block for Parallel Sides

This operation is, apparently, simple enough, but care must be exercised if accuracy is required. The piece is supported on parallels and clamped in a vise. In fastening it one must be careful to be sure that there are no particles of dirt or chips between the parallels and bottom of piece, and that it is tamped down so that it seats properly when the vise is firmly clamped.

A plain milling cutter with spiral teeth is used, as this is best where a finished surface is desired. A cutter with nicked teeth would be better if considerable stock were to be taken off.

The table is fed longitudinally, and it should be noted that lubricant is used upon the cutter.

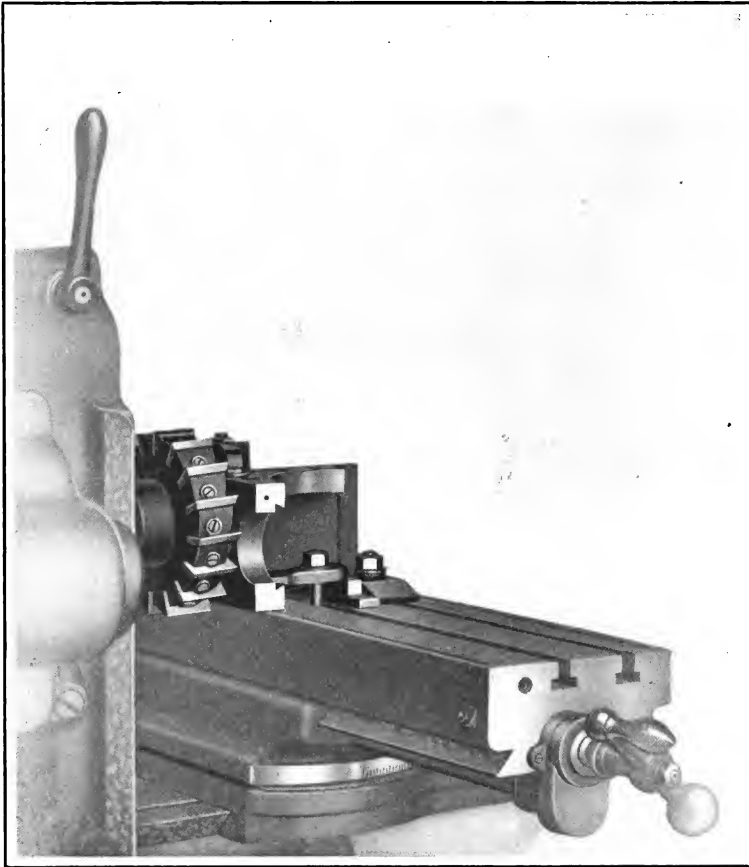


Milling Seat on Bottom of Bracket

The flat surface and V on a bracket can be milled in the manner shown in this cut. The bracket illustrated is of cast iron, and is clamped to the table by a bolt passing through a hole at the outer end of the casting, and a strap and bolt near the middle of the piece.

A 60° angular cutter is used and the table is fed longitudinally. A smaller cutter of the same angle can be used, but it will require several cuts to finish the piece.

This job, and others of a similar character, can also be done to good advantage on a vertical spindle milling machine or a horizontal machine fitted with a vertical spindle attachment.

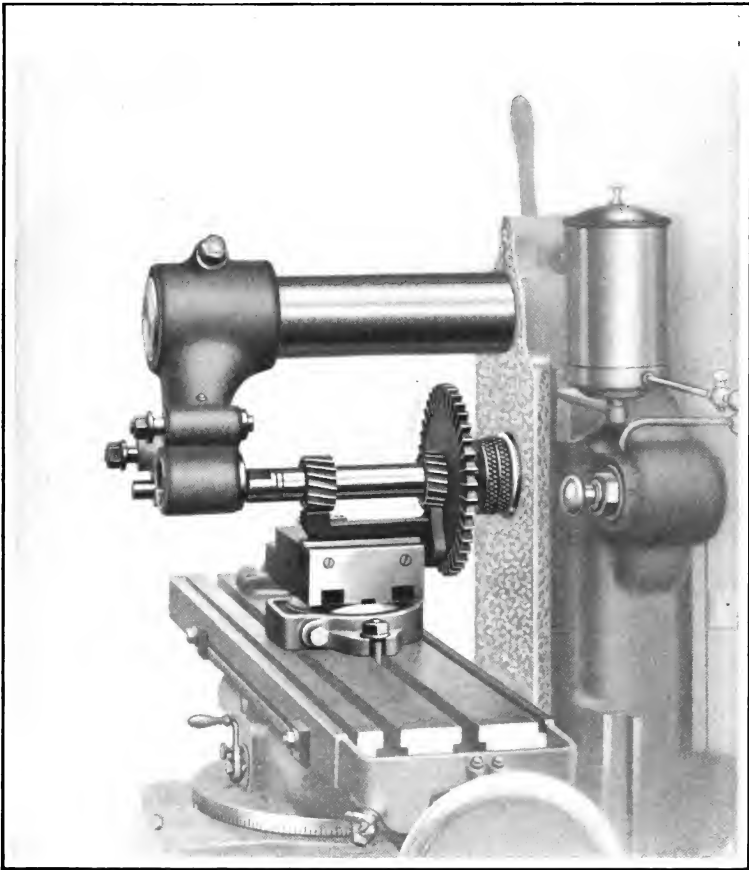


Face Milling Surface of Spiral Head Casting

This operation illustrates the use of a face milling cutter with inserted teeth for surfacing a piece of work.

The piece, which is of cast iron, is clamped to a knee to keep it square with the spindle. A strap in front prevents it being pushed away from the cutter, toward which there is a strong tendency.

The cutter is mounted directly on the nose of the spindle, and, in feeding, the work is moved longitudinally from right to left, or so as to force the work down against the table, rather than raise it. Only one cut is taken over the surface.

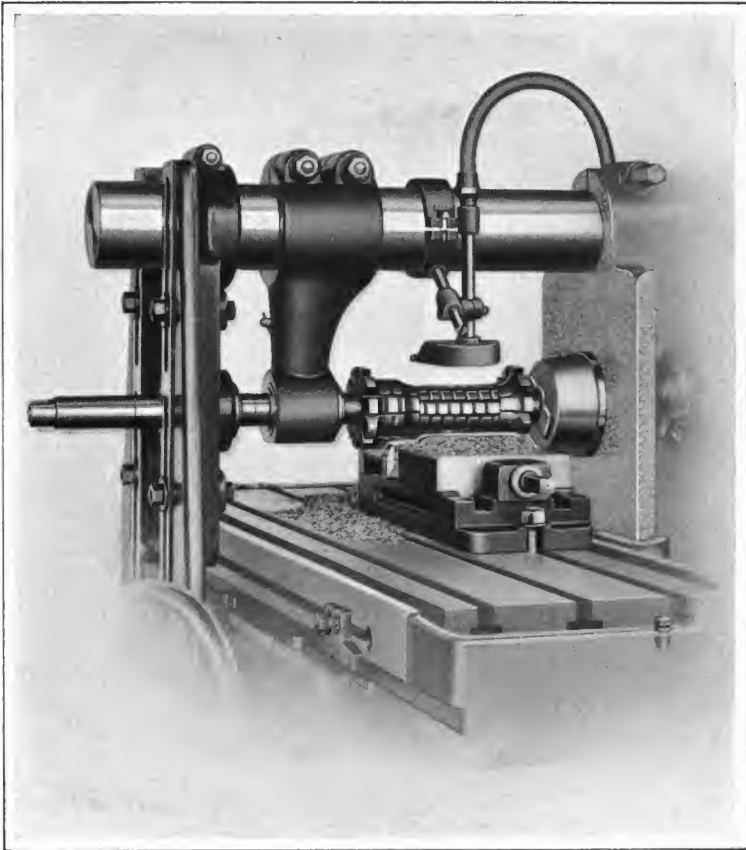


Milling Three Surfaces at One Setting

An example of light gang milling is shown in the accompanying cut. The two top surfaces and one end of the casting are being milled simultaneously by the use of two plain milling cutters, and a larger side milling cutter.

The two plain milling cutters are $2\frac{1}{2}$ " diameter, $1\frac{1}{4}$ " and $\frac{7}{8}$ " wide respectively; and the side milling cutter is 8" in diameter. To equalize the cutting speeds due to the wide difference between the diameters of the cutters, the large one is made of high speed steel, and the small ones of carbon steel.

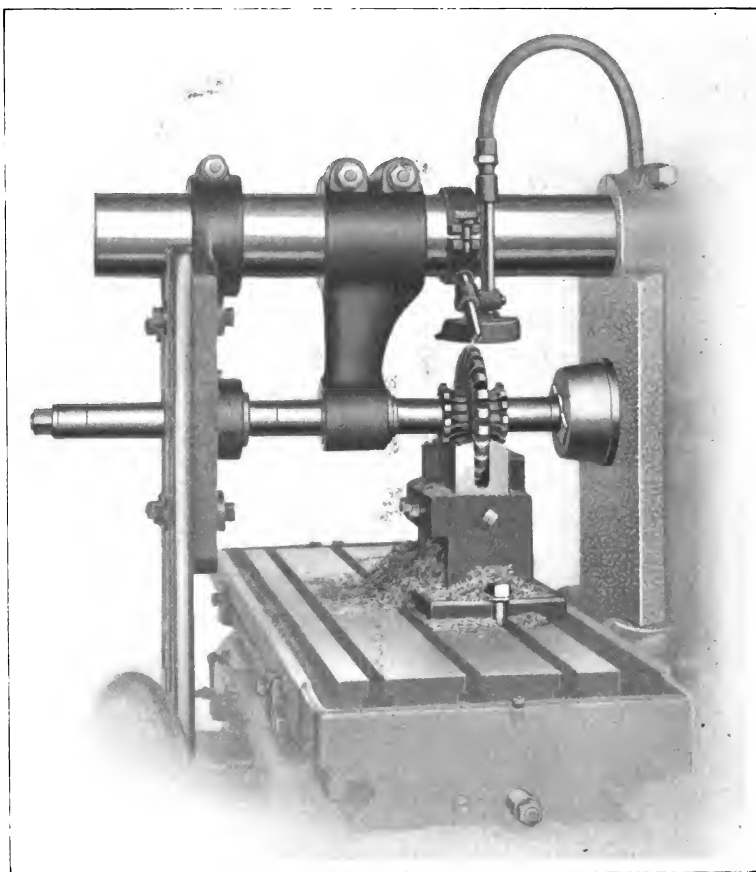
If only one or two pieces are wanted, this work can be done more speedily with an end mill, as it takes more time to set up and adjust the three cutters shown above than would be required for making special settings with an end mill.



**Milling Outline on Reverse Gear Plates on a
No. 2 B Heavy Plain Milling Machine**

These plates are used on the spiral head to support the intermediate, or reverse gear. Before milling, a hole is drilled at each end of the plate, and then several plates are strung on rods. The ends of the rods are allowed to protrude, and slots are cut in the vise jaws to receive them. When one side of the plates is milled, the vise is unclamped and the plates are turned over, dropping the ends of the rods again into the slots in the vise jaws. The other side of the plates is then milled, producing the entire outline of several plates at two cuts and insuring duplication.

The outline is cut from the solid, and the material is steel, hence the cut is a heavy one. Lard oil or soda water is used as a cutting lubricant.

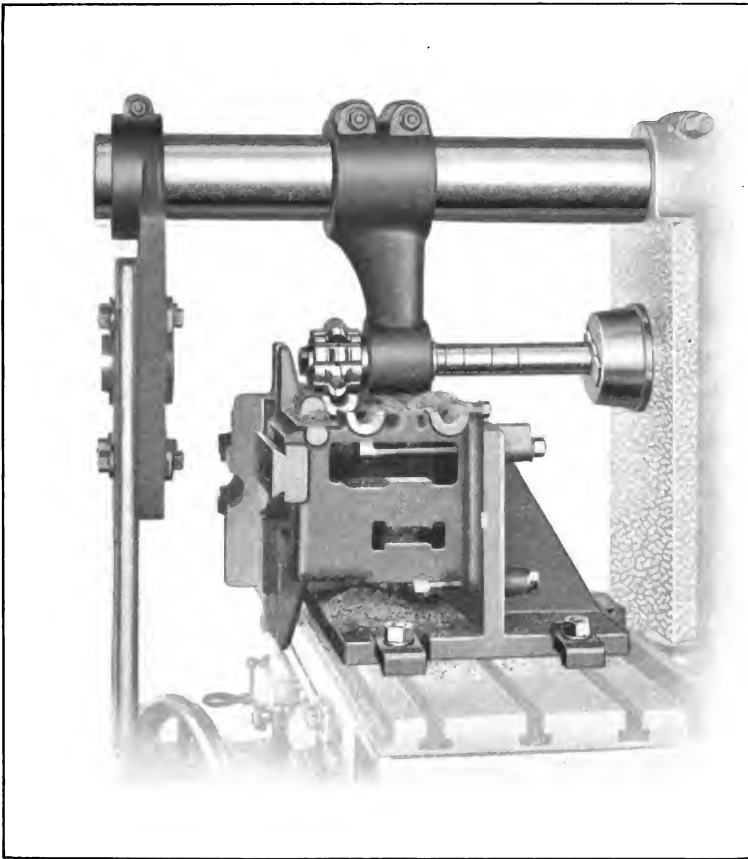


**Milling End and Slot in Spiral Head Work Drivers on a
No. 3 B Heavy Plain Milling Machine**

Several of these work drivers are placed in the special fixture shown and clamped by means of the set screws at the side and end.

The cutter at one traverse mills the curved end and the deep slot in the plates. Then the set screws are slackened, each plate is reversed in the fixture, and the other ends are milled to duplicate the first.

The middle cutter is $7\frac{1}{2}$ " in diameter, and as the cut is taken from solid steel, a heavy machine with rigid support for the cutter arbor is required. Lard oil or soda water is used as a cutting lubricant in this operation.

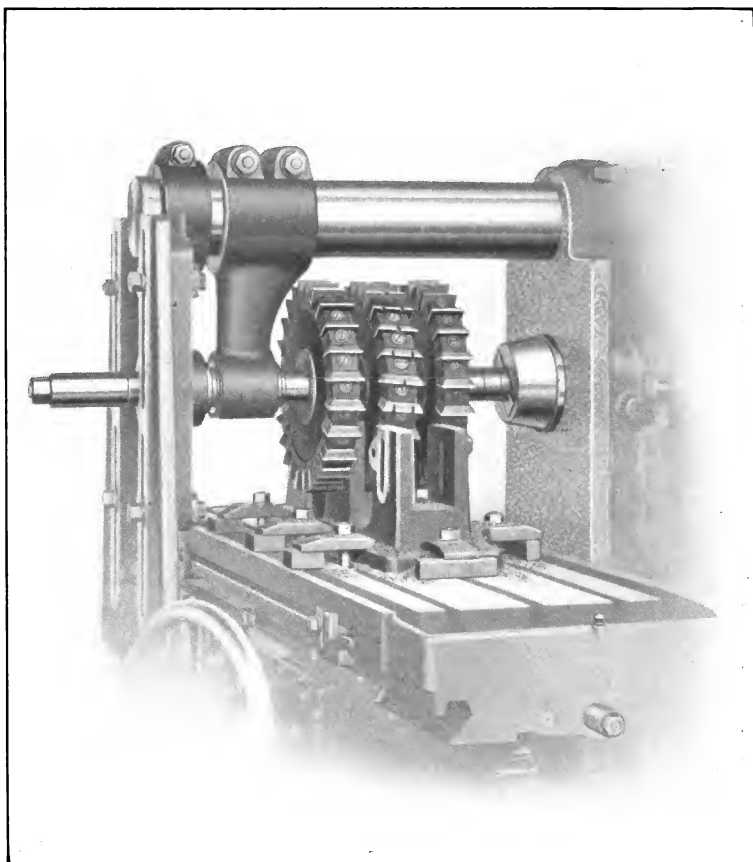


**Milling Bearings on Automatic Screw Machine Bed on a
No. 3 B Heavy Plain Milling Machine**

It is the usual practice to put the caps on bearings, and bore them out, but this operation shows how bearings can be milled to good advantage. The caps can be milled at another operation so accurately that it is only necessary to pass a reamer through the bearings after the caps are put on to line them up exactly.

The cutter is made in two parts that are interlocking, and thin washers may be packed between to maintain the correct diameter.

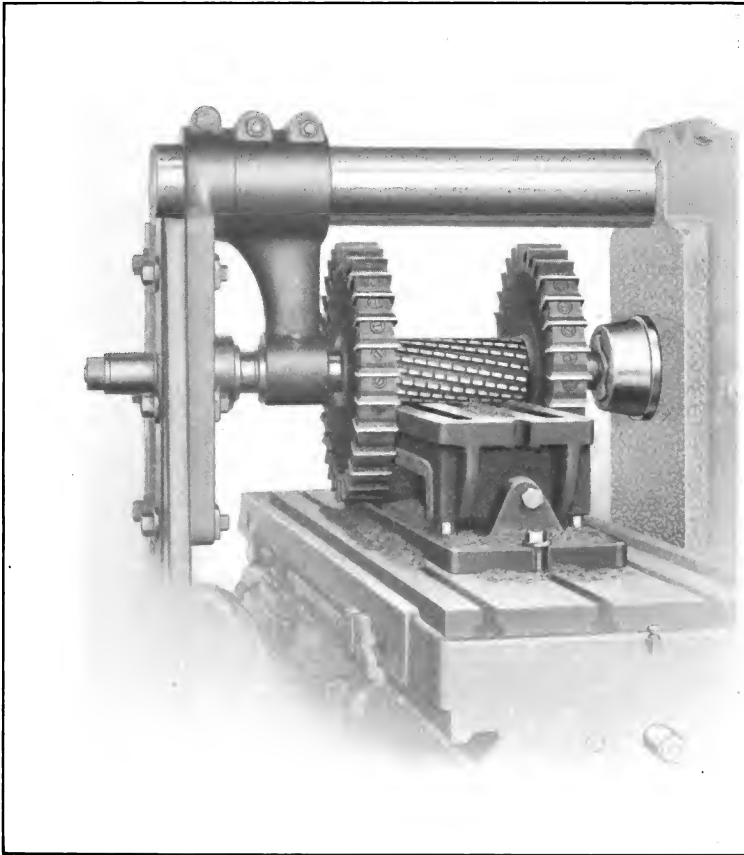
It should also be noted that the cutter has to be located at the end of the arbor because of the high projection on the casting.



**Milling Sides of Foot-stock for Spiral Head on a
No. 3 B Heavy Plain Milling Machine**

This operation is of interest largely because the height of the sides milled is such that a gang of cutters of unusually large diameter is required. Three castings are lined up, strapped to the table, and milled at one cut. The outsides of the uprights are surfaced, and the space between is cut to the required width.

The cutters employed are inserted tooth side milling cutters 12 inches in diameter. Teeth are set parallel with the axis in the outside cutters, as their width is not great. In the middle cutter, which is wider, the teeth are set at an angle to give a shearing cut, and are nicked to break up the chips.



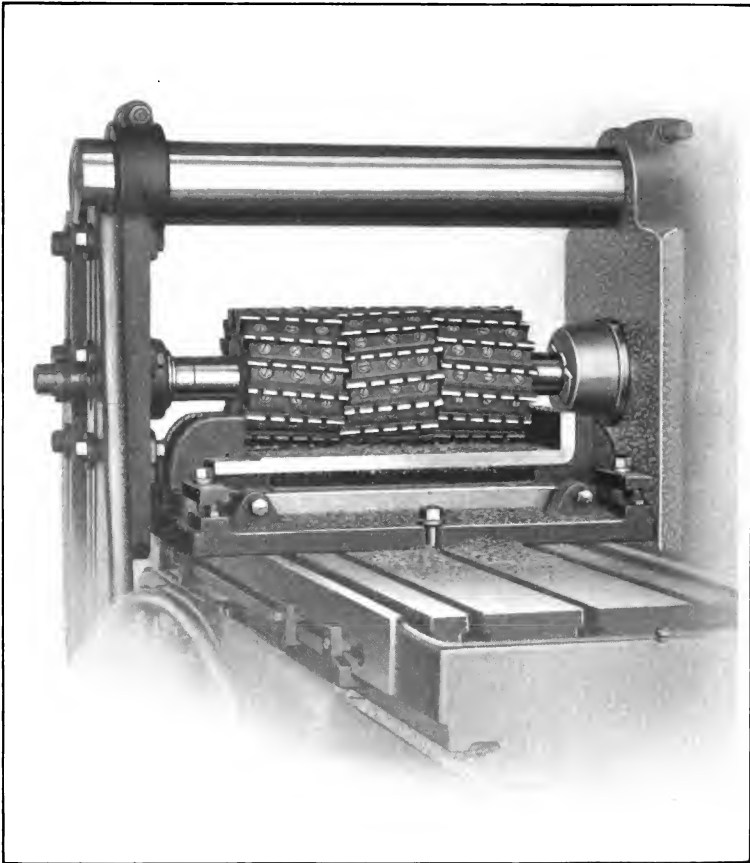
**Surfacing Bottom and Sides of Milling Machine Vise Base on a
No. 4 B Heavy Plain Milling Machine**

The possibility of milling the deep sides of a casting, and at the same time surfacing the bottom, is illustrated in this cut.

A special fixture is employed to hold the piece, which is supported on three pins and located in position against stops. Set screws at both ends of the fixture clamp the piece.

The two side milling cutters shown are 16 inches in diameter, and the nicked tooth spiral cutter in the middle is 4 inches in diameter.

Only one casting can be milled at a time, owing to the distance it takes for the large cutters to clear the work at the beginning and end of the cut.

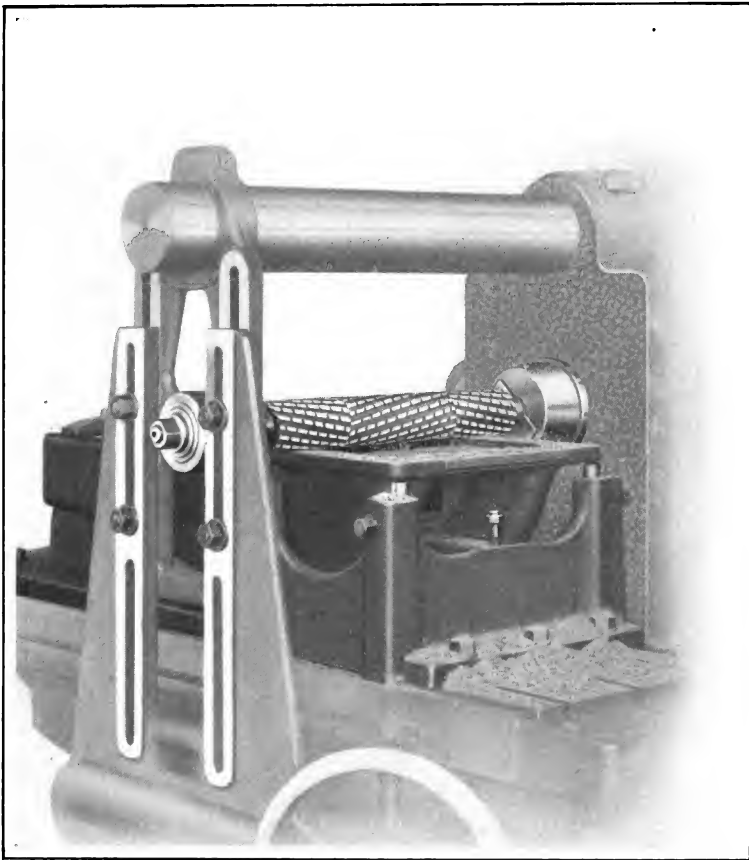


**Milling Slide Seat of Vise on a No. 4 B Heavy
Plain Milling Machine**

This is the second operation on the casting shown in the preceding illustration. The cut is a simple, but heavy one, being 17 inches wide and $\frac{3}{8}$ of an inch deep.

Interlocking inserted tooth milling cutters, 8 inches in diameter, are used, the large diameter being necessary because of the height of the casting at the ends.

Where the end thrust on the arbor cannot be equalized, the greatest thrust should be toward the spindle nose. Thus in the above operation, two right-hand angle cutters are used against one left-hand, and the greatest thrust is toward the spindle nose.

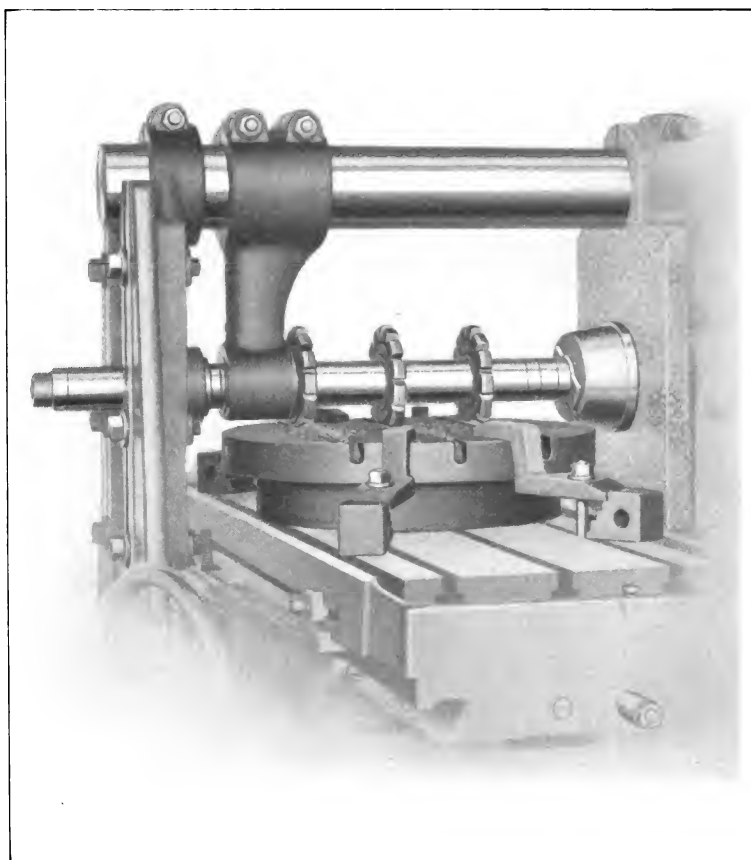


**Surfacing Large Casting on a No. 4 B Heavy
Plain Milling Machine**

An excellent example of heavy, plain gang milling is shown in this illustration. The surface being milled is $15\frac{1}{2}$ " wide, and the casting is held in a special fixture.

The table is fed longitudinally against the direction in which the cutters revolve. As the cut is comparatively heavy, nicked tooth cutters are employed, and it will be noticed that the thrust is mostly toward the spindle nose.

For such work as this, where considerable power is required to drive the cutters, the Constant Speed drive machine is superior to the Cone drive type.



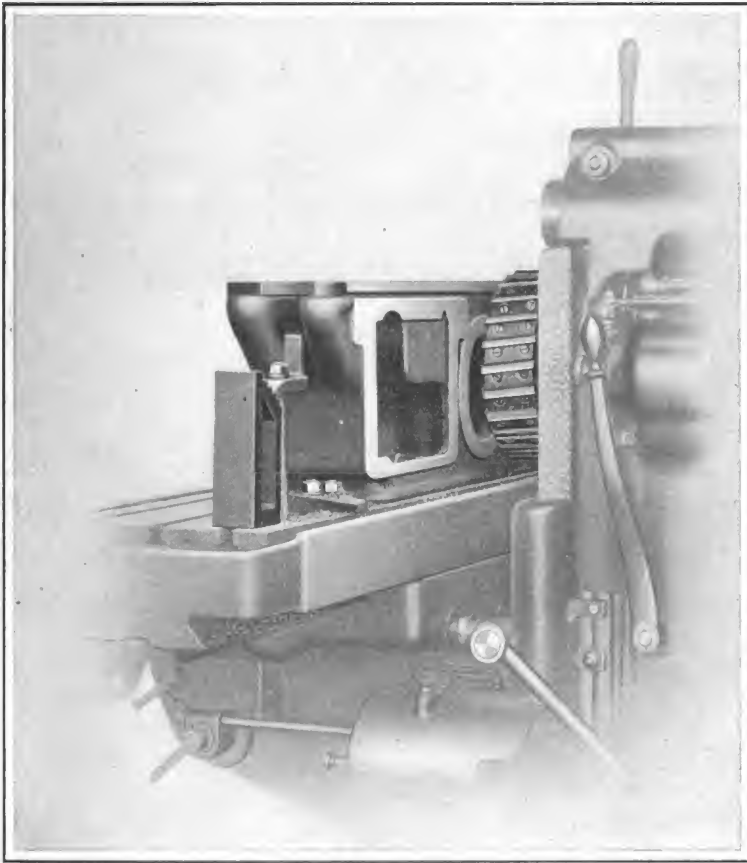
**Cutting Slots in Circular Milling Attachment Table on a
No. 4 B Heavy Plain Milling Machine**

Three parallel slots are cut in the top of this table by spacing three cutters on the arbor by means of collars.

Considerable power is required for the operation, as the slots are cut from solid stock to the depth of $\frac{7}{8}$ of an inch, and $\frac{1}{8}$ of an inch wide.

Specially shaped straps are necessary to fasten the work to the table, in order to make use of cutters of small diameter.

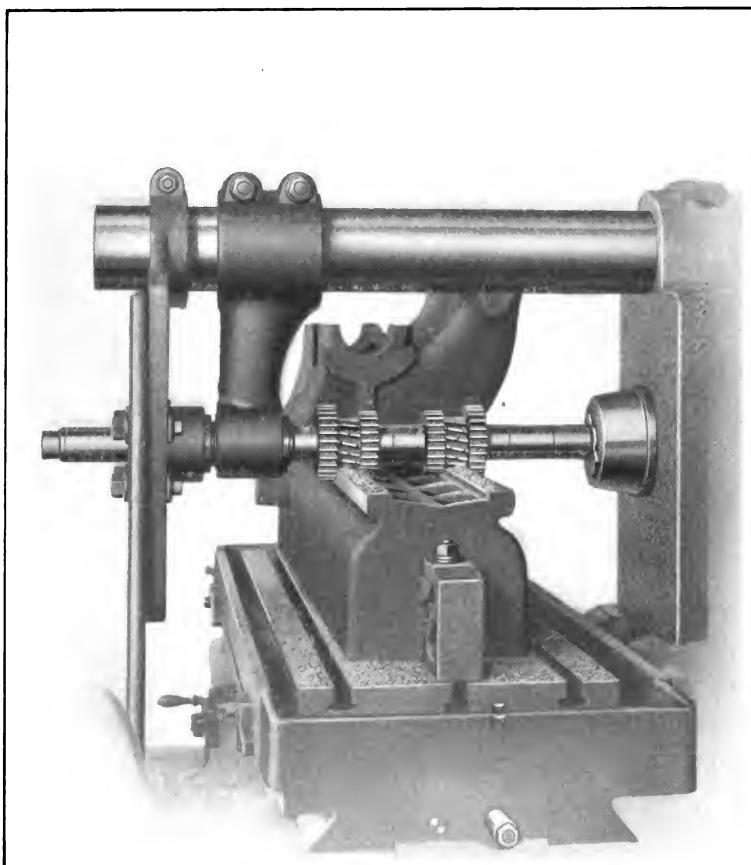
The cutters employed are regular stocking cutters 6 inches in diameter, and are rigidly supported on the arbor.



**Face Milling Front of Grinding Machine Bed on a
No. 3 B Heavy Plain Milling Machine**

Jobs similar to this are done on the planer in many shops, but by setting the work up as shown, it is often possible to get a greater production from the milling machine.

The bed is lined up against a parallel inserted in one of the table T slots, so that there is no trouble lining up each successive casting. The saddle does not have to be readjusted for depth of cut each time. Straps at each end hold the piece on the table, and stops set in the table T slots prevent the tendency of the casting to slip, due to the action of the cutter.

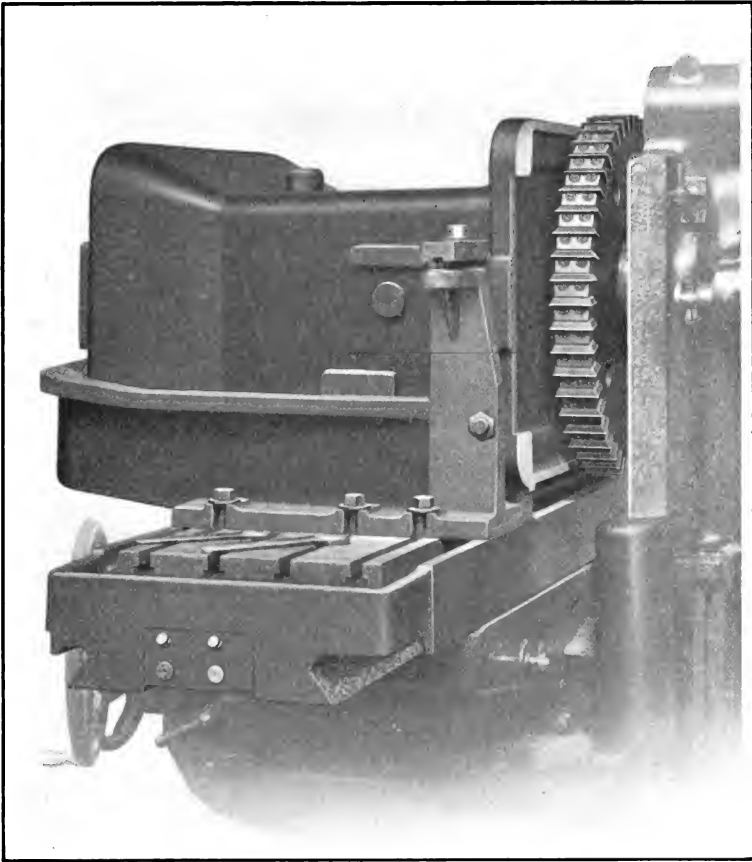


**Milling Ways on a Screw Machine Bed on a No. 4 B
Heavy Plain Milling Machine**

The value of gang milling, and the advantages of the milling machine over the planer, are very apparent in this operation, for it is essential that the ways on every bed be exact duplicates in width and distance apart. Once the gang of cutters is accurately set, each succeeding casting must necessarily be a duplicate of the first.

The bed has a boss cast on each end by means of which it is clamped directly to the table. After milling, the two bosses are taken off.

The gang of cutters is composed of four side milling cutters, and two plain spiral milling cutters with nicked teeth. The arbor is firmly supported in the arm braces, and the arbor yoke is employed to bring a bearing nearer the cutters.



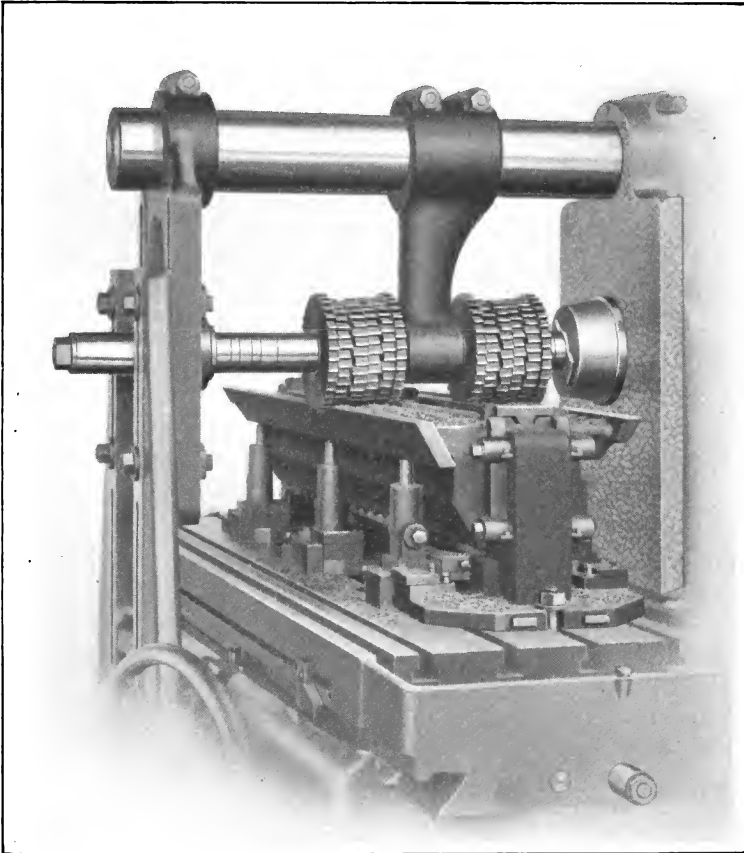
**Surfacing Bottom of Screw Machine Bed on a No. 5 B
Heavy Plain Milling Machine**

This illustration shows the possibilities of the milling machine for doing work that might be termed in many shops as suitable for the planer only.

The extreme weight, large size and powerful leverage due to the large overhang of the piece, are all factors that serve to make this an unusual milling job that requires a rigid machine.

The work and fixture together weigh over 1000 pounds, and the piece as it is fastened to the table is 25" high, and extends 35" out from the cutter.

Another unusual point is the size of the inserted tooth face milling cutter, which is 26" in diameter.

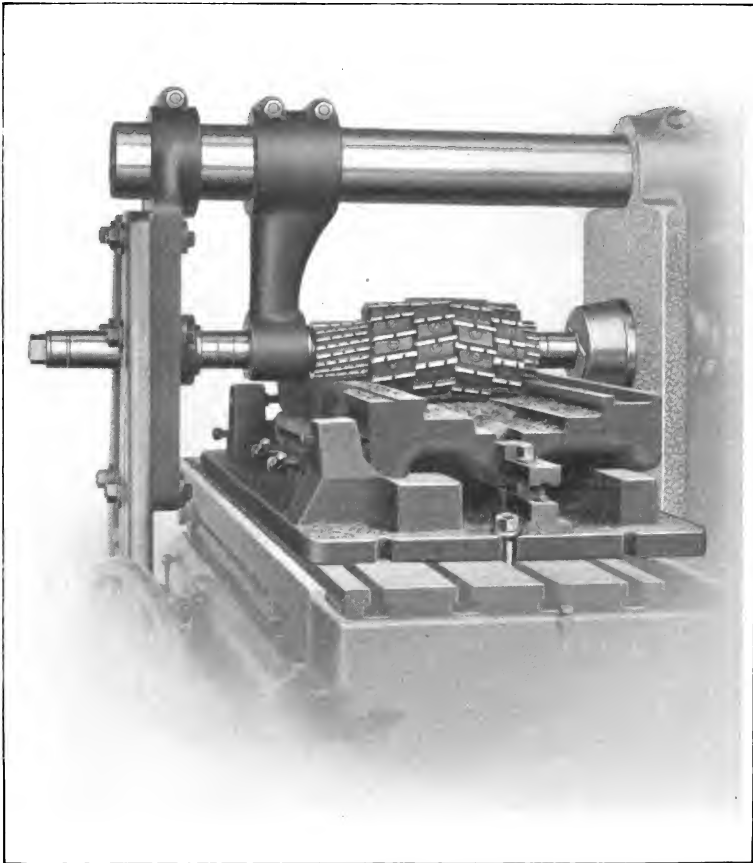


**Milling Pair of Grinding Machine Tables on a No. 5 B
Heavy Plain Grinding Machine**

Where the size of machine and character of work permit, it is very advantageous to mill more than one piece at a time. This operation illustrates how two plain grinding machine tables are milled simultaneously.

The two tables are held in a fixture, the essential features of which are plainly apparent in the cut. There are two sets of cutters made up of plain milling cutters and interlocking mills.

Another feature of this operation is the placing of the arbor yoke between the two sets of cutters.



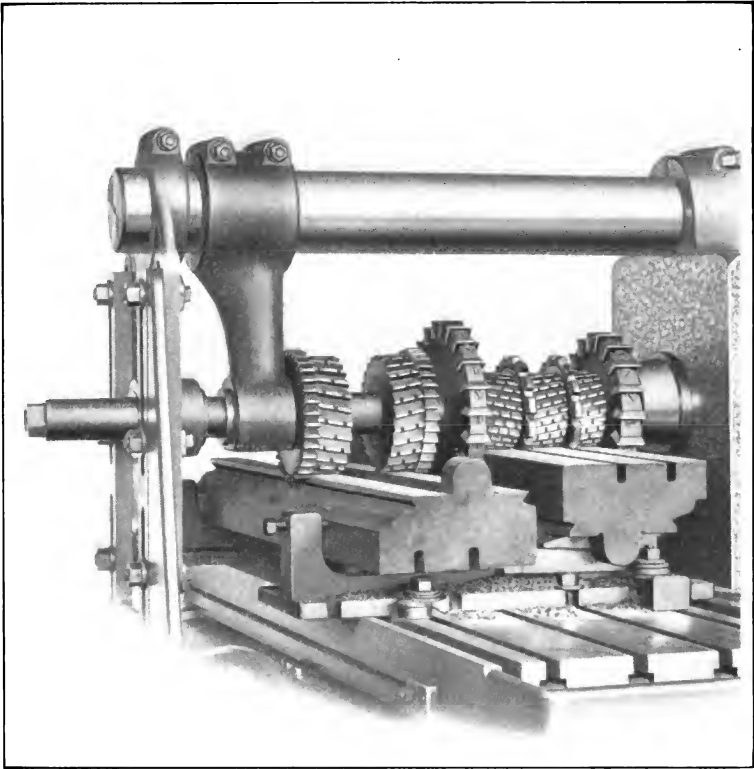
**Milling Saddle of Vertical Spindle Milling Machine
on a No. 5 B Heavy Plain Milling Machine**

Milling machines are employed wherever possible in manufacturing parts of milling machines in our works. The operation above shows one example of this.

The width of cut on this saddle is 17 inches, and $\frac{3}{8}$ of an inch of stock is removed, making a heavy cut.

The work is held in a special fixture, as it can be more firmly clamped, and more quickly put in place and removed from the table.

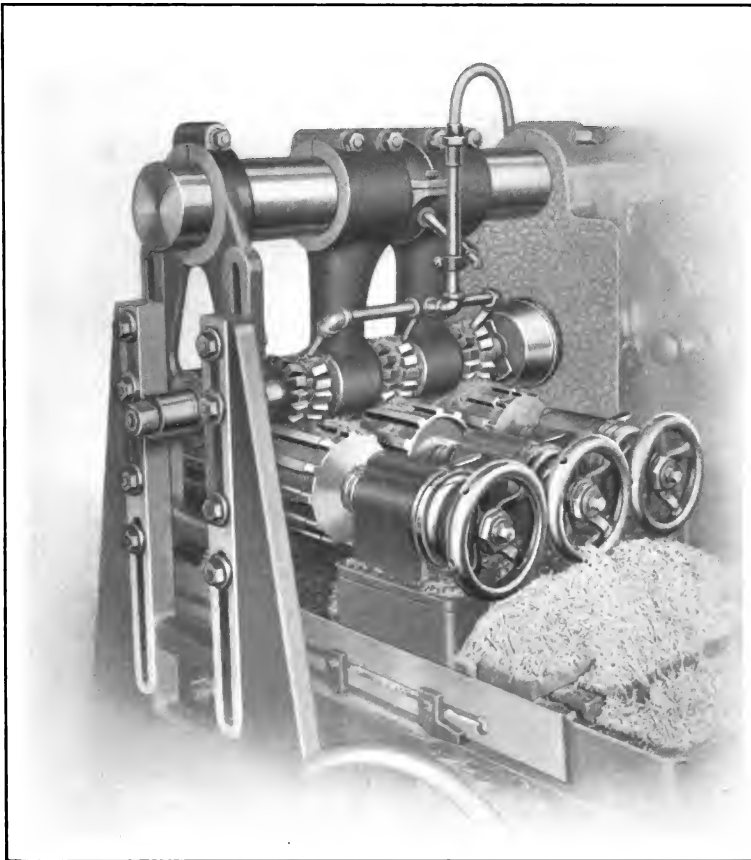
All of the cutters have nicked teeth, and the larger ones have inserted teeth. It should also be noted that end thrust on the arbor is equalized by using cutters of both right and left-hand angle teeth.



**Heavy Gang Milling of Milling Machine Tables
on a No. 5 B Heavy Plain Milling Machine**

The job shown above is that of milling the cast iron tables of small milling machines, and it is an interesting example, illustrative of the economy of gang milling. The top of one table and the bottom of another are milled simultaneously. The castings are held in a special fixture, and when one cut is taken, the piece at the left is removed, the one on the right turned over so that the ways on the bottom can be cut, and a new casting is put on the right-hand side of the fixture.

The table is fed longitudinally from left to right, and the cutters comprise four side milling cutters, one $9\frac{1}{2}$ " , one $11\frac{1}{2}$ " , and two $7\frac{3}{8}$ " in diameter; five plain milling cutters, two $7\frac{1}{8}$ " , and three $4\frac{3}{4}$ " in diameter; and two slotting cutters, $6\frac{23}{32}$ " in diameter.



**Cutting Two Grooves in Six Steel Cores at One Traverse
on a No. 5 B Heavy Plain Milling Machine**

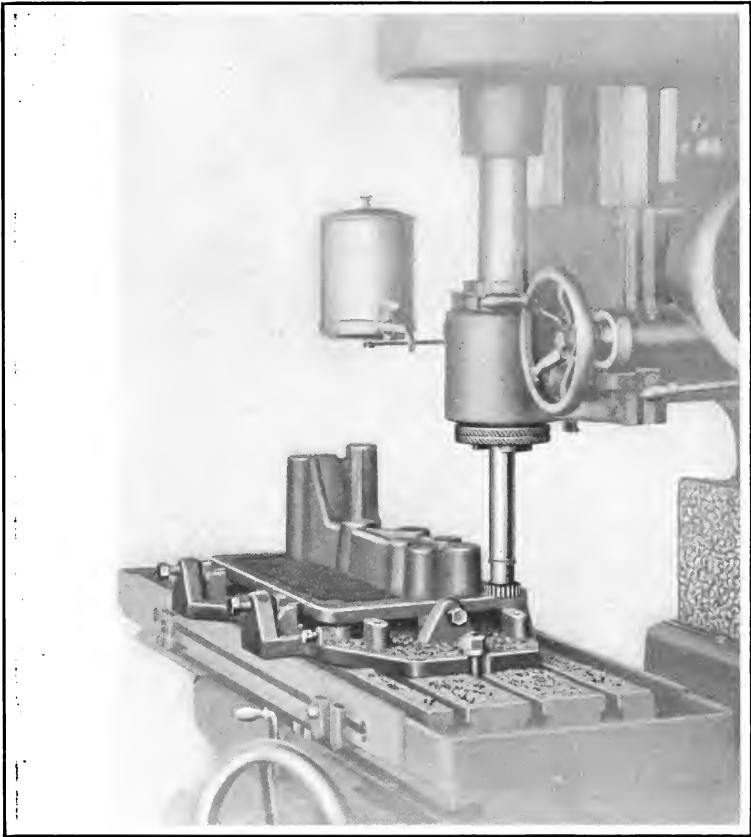
This illustration shows an unusually heavy milling operation, consisting of cutting two grooves, each 1.17" wide and $\frac{1}{8}$ " deep, in six steel forgings at one traverse of the table.

Three sets of index centres of a special design are employed, and two steel cores are mounted on the arbor on each pair of centres.

The cutters are of a special form to cut two grooves and the top of the intervening space between the grooves.

For such a cut as this, a large arbor is required, and it must be very rigidly supported; intermediate arbor yokes are, therefore, placed between the cutters.

Lard oil is used as a cutting lubricant.



**Surfacing Face of a Grinding Machine Apron on a
No. 3 Vertical Spindle Milling Machine**

A vertical spindle milling machine is peculiarly adapted to work having a long projecting hub, or where it is necessary to surface off some part inside, such as in gear cases. The operation above is typical of such work, and shows a casting that must be milled all around the outside edge.

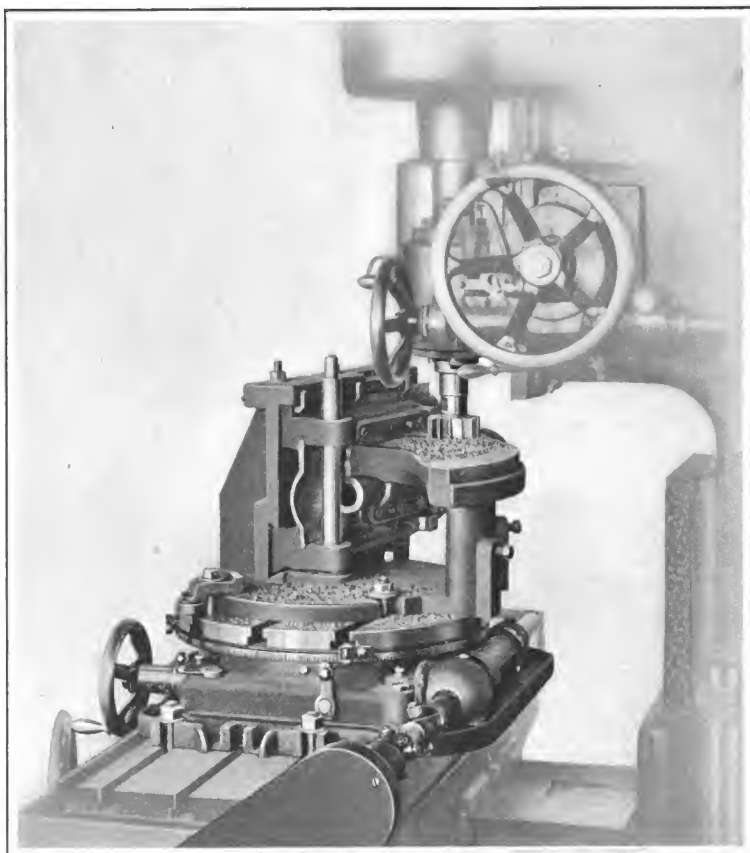
The casting is clamped in a special fixture, and a shell end mill is employed. The outline of the edge is followed by using the horizontal and transverse table feeds alternately for the different sides.



**Milling a Dovetail in Plain Milling Machine Saddle
on a No. 3 Vertical Spindle Milling Machine**

The casting is held on a special fixture which has a slide corresponding to the slide on the top of the knee of the milling machine. The piece can be removed by simply loosening the gib.

The top plate of the fixture also swivels, so that one side of the ways can be milled on an angle for a taper gib. Both operations are, therefore, completed at one setting of the fixture, thus insuring the surfaces being milled in relation to each other. A 50° angular cutter is used for this operation.

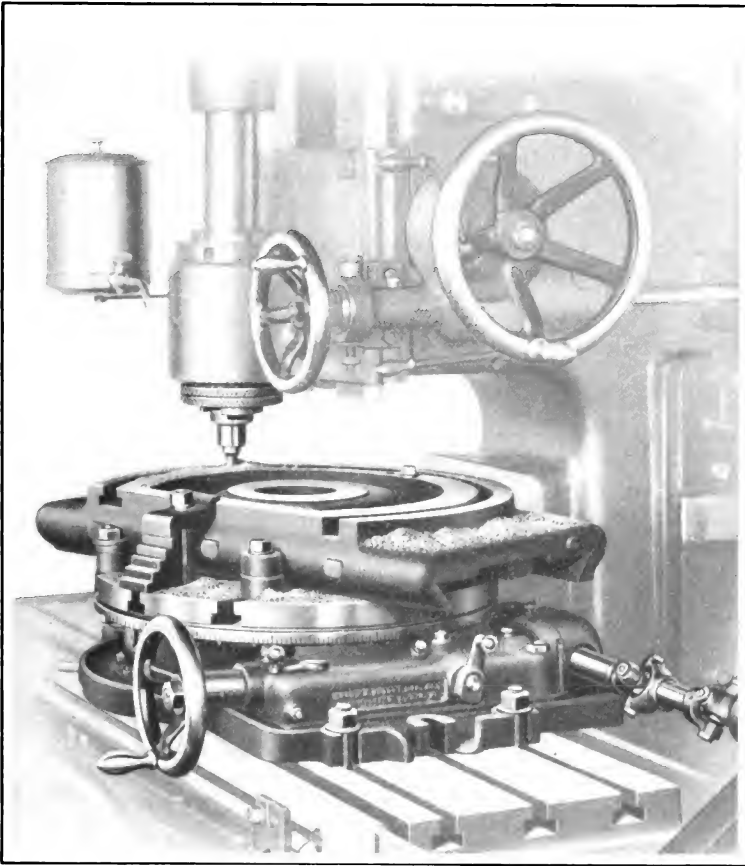


**Surfacing and Milling Edge of Curved Casting on a
No. 3 Vertical Spindle Milling Machine**

This illustration shows the use of a power-driven circular milling attachment, in connection with a vertical spindle milling machine for milling the surface and edge of a cutter carriage of an automatic gear cutting machine.

The special fixture employed is more for the purpose of milling the outside curved edge of the casting than for the operation shown. It has a way cut to correspond to that on the back of the casting, and an arbor inserted through two holes in the piece and into the centre of the circular milling attachment insures the outer edge being milled concentric with the holes.

All necessary movement is obtained from the circular attachment.

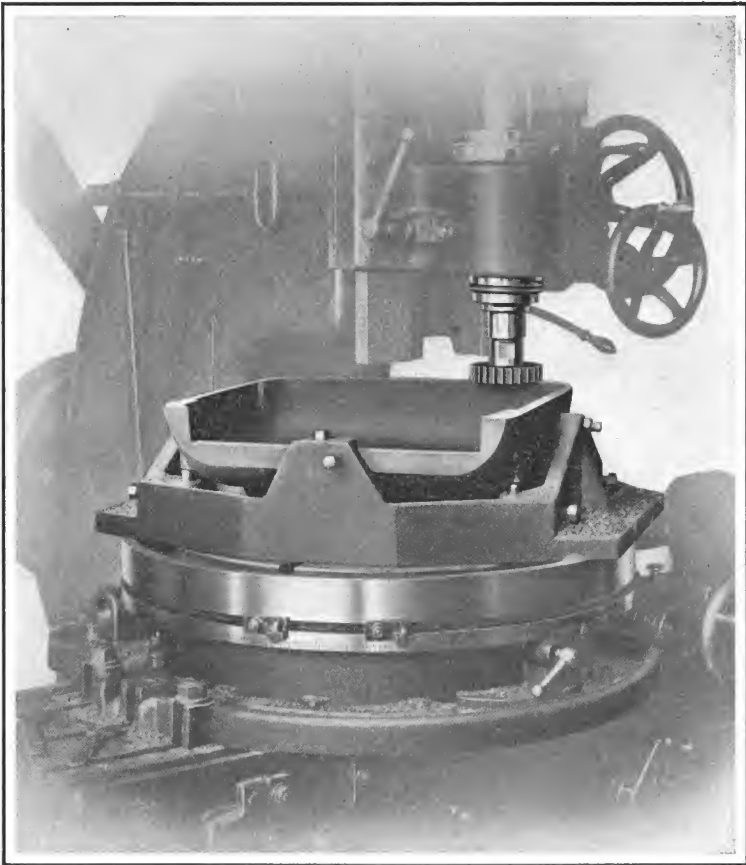


**Cutting a Circular T Slot in Universal Milling Machine Saddle
on a No. 3 Vertical Spindle Milling Machine**

The operation shown above illustrates another excellent example of the use of the circular milling attachment in connection with a vertical spindle milling machine, for cutting the circular T slot in the saddle of a universal milling machine.

The piece of work is centred by placing it over a stud and bushing inserted in the hole in the centre of the circular attachment table. It is prevented from swinging by four bolts with washers, two of which are shown, and a strap from a stepped block across to the casting on each side fastens it to the table.

The first, or plain, slot is cut out on a boring mill or can be milled at the same setting shown above, using a two-lipped end mill, which is then replaced by the T slot cutter.

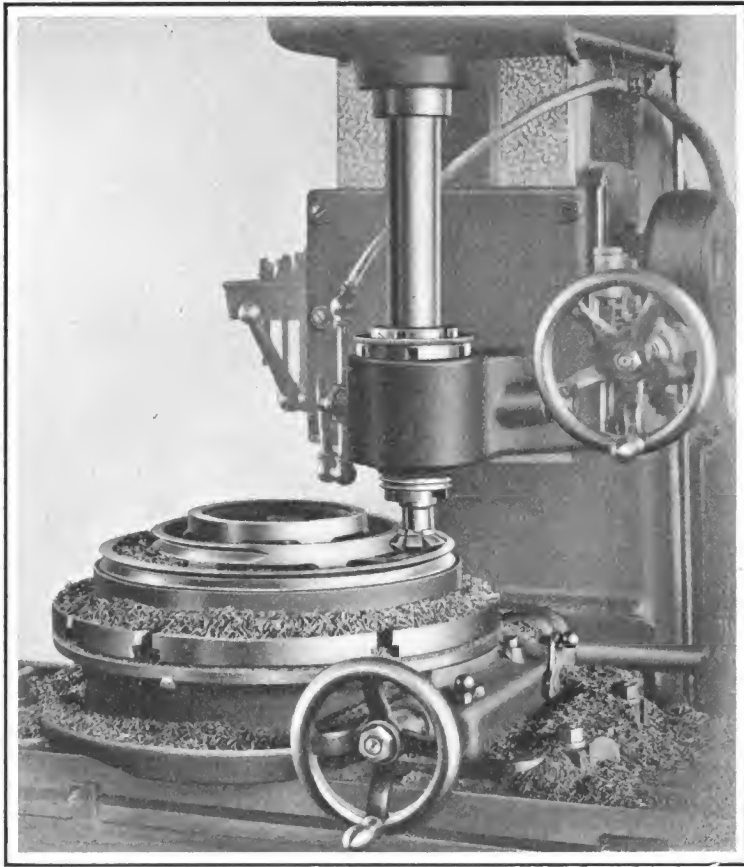


**An Interesting Use of a Circular Milling Attachment on the
No. 3 Vertical Spindle Milling Machine**

Surfacing such a casting as this would ordinarily be done by following the outline of the piece of work, using the longitudinal and transverse automatic table feeds. But this necessitates shifting the feeds at each corner of the casting. A better way was found when the casting and fixture were clamped to the table of a circular milling attachment and fed in a circular path beneath the cutter.

The shorter distance the mill has to travel, the time saved in shifting feeds, and the fact that the operator does not have to give his undivided attention to the job, are all important advantages.

The metal is $\frac{1}{2}$ " thick. By the usual method, it is difficult to secure the flat, oil-tight surface that is easily obtained in the way described above.

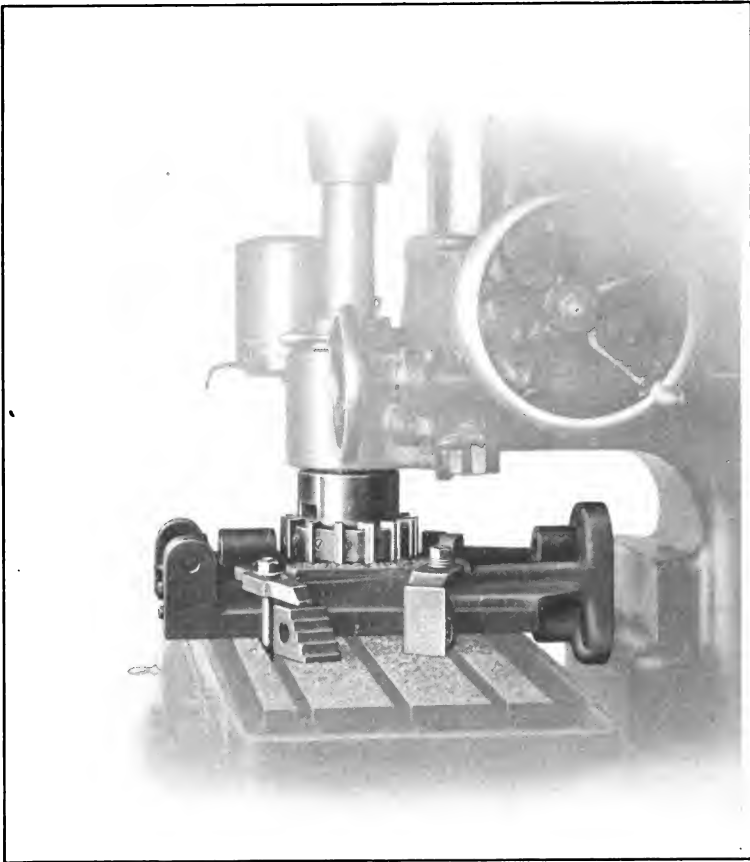


**Milling Grooves in Rim of Pulley on the No. 3
Vertical Spindle Milling Machine**

Here a vertical spindle machine equipped with a circular milling attachment is shown milling belt grooves in the rim of a three step pulley.

The pulley is easily fastened in place and a continuous cut is taken around the rim, using the automatic feed of the attachment. The knee is then lowered to bring the cutter at the right height for the next smaller step and the table is moved longitudinally to get the correct depth of cut. This operation is repeated for the smallest step and the piece is finished.

This operation can also be done on a horizontal milling machine when equipped with both vertical spindle and circular milling attachments.

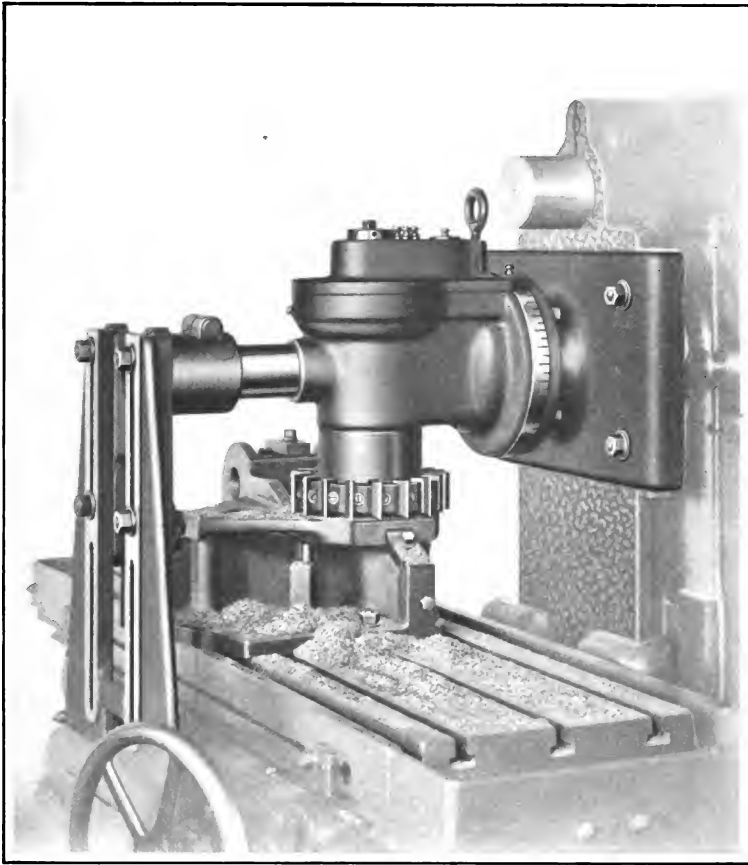


**Milling a Plain Surface on a No. 3 Vertical Spindle
Milling Machine**

It is advisable in milling castings such as that shown, to do the work on a vertical spindle machine, as it is much more convenient. If a horizontal spindle machine is employed, and the work is clamped to the table, plain cutters of unusually large diameter are required, and when a face milling cutter is used, the work must be clamped to a knee. This, too, is unhandy when the casting is somewhat unwieldy.

The piece of work illustrated is of cast iron, and it is fastened directly to the surface of the table by means of straps extending from step blocks to the casting and secured in place by bolts set in the table T slots.

The face mill employed has inserted teeth. The table may be fed longitudinally in either direction.

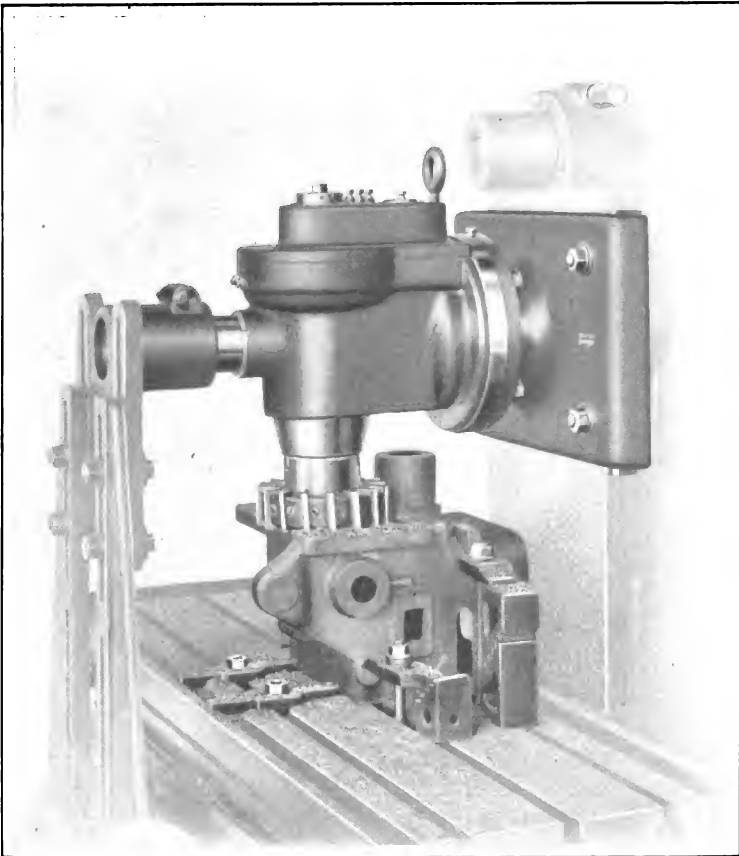


**Face Milling, Using Heavy Vertical Spindle Attachment on a
No. 4 B Heavy Plain Milling Machine**

It will be seen from the above cut that in shops where the volume of work does not warrant installing a vertical spindle milling machine, the operation that would generally be done on that machine can be done on a horizontal spindle machine equipped with a vertical spindle attachment. The illustration shows a very heavy style of attachment.

The operation is that of face milling a surface on a cast iron piece which is held in a special jig upon the table.

The cutter is of the inserted tooth style, $9\frac{1}{2}$ " in diameter. The table is fed from left to right on account of projections at end of casting.



**Face Milling, Using Heavy Vertical Spindle Attachment on a
No. 4 B Heavy Plain Milling Machine**

This operation is essentially the same as the one just described, with the exception that the casting in the first instance was fastened in a special fixture, while in this case it is clamped directly to the table and the cutter is held on an arbor.

The method of clamping needs little explanation, as it is very clearly shown in the illustration.

If it were not for the height of the hub at the right of the cutter, this job could easily be done without the attachment with plain milling cutters.

The cutter is $7\frac{1}{2}$ " in diameter and has inserted teeth.

CHAPTER VIII

Milling Operations—Gear Cutting

We do not propose in this chapter to go deeply into the subject of gearing, for it would be impossible to properly treat it in so limited a space. Neither do we intend to describe the manner in which gears are cut on automatic gear cutting machines designed especially for that purpose. Our object is rather to give a few practical points applying to the cutting of different kinds of gears on a milling machine, and to show illustrations of how various gear cutting jobs and work of a kindred nature can be set up. Anyone desirous of making a detailed study of gears is referred to the many books now published that are devoted exclusively to the subject, among which are our "Practical Treatise on Gearing," and "Formulas in Gearing."

Cutting Spur Gears. The first things that are necessary to know in order to cut a spur gear, are the pitch, either diametral or circular, and number of teeth required. These must be had in order to select the correct cutter to use.

We make eight cutters for each pitch, as follows:

No. 1	cutter will cut wheels from 135 teeth to a rack
No. 2	" " " " " 55 " " 134 teeth
No. 3	" " " " " 35 " " 54 "
No. 4	" " " " " 26 " " 34 "
No. 5	" " " " " 21 " " 25 "
No. 6	" " " " " 17 " " 20 "
No. 7	" " " " " 14 " " 16 "
No. 8	" " " " " with 12 " and 13 "

For those who require a finer division of the number of teeth to be cut with each cutter than can be cut with the regular numbers listed above, we can furnish half numbers in cutters from 2 to 8 pitch inclusive, as follows:

No. 1½	cutter will cut wheels from 80 teeth to 134 teeth
No. 2½	" " " " " 42 " " 54 "
No. 3½	" " " " " 30 " " 34 "
No. 4½	" " " " " 23 " " 25 "
No. 5½	" " " " " with 19 " and 20 "
No. 6½	" " " " " 15 " " 16 "
No. 7½	" " " " " 13 "

Care should be exercised that the teeth of a cutter selected are ground radially and equidistant, for the teeth are so formed that unless ground in this manner, the correct shape is not produced in the work.

If a universal milling machine is employed, the table should be set at exact right angles to the arbor by the graduations on the saddle. This precaution does not have to be taken on plain machines, as the table is fixed at right angles to the spindle or arbor.

Set Cutter Central. It is essential that the cutter be exactly central with the axis of the gear blank, especially when the gear is to be run fast, otherwise the gear will be cut "off centre," and will run more noisily in one direction than in the other. It may be set centrally as follows: Set the table or the cutter on the arbor as nearly as possible in position; fasten the gear blank, or preferably an odd blank of about the size of the gear to be cut, on an arbor and lock it in position on the centres. Take a single cut, then remove the blank from the arbor, turn it end for end and put it back on. Permit the blank to remain loose on the arbor, and see if the cutter will pass through the groove already cut without taking any stock off on either side. If the cutter is not exactly central, stock will be cut from the upper part of one side of the groove and from the lower part of the opposite side of the groove. If this is found to be the case, the table can be slightly adjusted to compensate for the error and another trial cut taken.

Some of the gear cutters made by us have a line on the tops of the teeth that is central with the form, and for ordinary slow running gears, the cutter may be centred by bringing this line to coincide with the centre in the spiral head or foot-stock.

Measure Blanks. Measure all gear blanks carefully. It is impossible to cut correct running gears from blanks that are of the wrong diameter unless the error is small. The amount of error allowable in the diameter depends upon the pitch of the gear; the heavier the pitch, the greater the allowable error. It is better to return to the lathe any blanks that are oversize and throw away those that are turned very much undersize. If blanks are only slightly undersize, they can be cut by making allowance for the error in setting for depth of teeth, and the resultant gears will run satisfactorily, though not perfectly.

Secure Blank on Arbor. The next important step is to see that the work arbor runs true and that the blank does not spring it when

forced or tightened. A good method of holding blanks is on arbors, such as our milling machine cutter arbors, that have a taper shank to fit the index spindle; the outer end of the arbor being supported by the foot-stock centre. Another way of holding blanks is by means of a shank arbor with expanding bushing, such as our gear cutting machine "work arbors." A nut is located on the arbor at each end of the bushing, one nut forcing the bushing up on the arbor and holding the blank, while the other pushes the bushing off the taper and releases the gear when finished.

If a common arbor and dog are used, care should be taken that the tail of the dog is fastened between the set screws provided on the spiral head, so there will be no backlash between the index spindle and work; also see that the dog does not spring the arbor when it is clamped.

Set Knee for Depth of Cut. The depth of cut is regulated by the height of the knee of the machine. To make this setting, the knee is brought up until the cutter just touches the blank. Then the blank is moved out from under the cutter and the knee is raised the number of thousandths of an inch required for the depth of tooth, which can be ascertained from the tables on pages 321 to 324, or by dividing the constant 2.157 by the diametral pitch.

When raising the knee, use the graduated dial on the vertical hand feed screw for a guide to get the required depth, but be sure to take out any backlash that may exist before making an adjustment.

Testing for Correct Depth. To make certain that the depth of groove cut is correct and the size of teeth accurate, cut two grooves into the face of the blank far enough so that the full form of the tooth is produced, and then measure the resultant tooth at the pitch line for thickness and the depth of the tooth to the pitch line. The correct thicknesses of spur gear teeth of different pitches at the pitch line are given in the tables on pages 321 to 324, or can be found by dividing the constant 1.57 by the diametral pitch.

By cutting only part way across the face of the blank the trial grooves can be quickly made and measured. If, on the other hand, the grooves are cut across the full width of the face, there is liability, under some conditions, of more stock being taken from these grooves when the actual cutting is commenced and the cutter is allowed to pass through the same grooves a second time, thus making these grooves too deep.

Chordal Thickness of Gear Teeth. When accurate measurements of gear teeth are required, it is necessary to work to the chordal

figures, t'' = thickness of tooth and s'' = distance from chord t'' to top of tooth (See Fig. 61).

These dimensions vary from the standard dimensions of tooth parts shown on pages 321 to 324. The fewer the number of teeth in the gear, the greater the variation.

The Table of Chordal Thickness t'' and Distances from Chord to top of Tooth s'' on page 325 gives these dimensions for gears of 1 diametral pitch. To obtain t'' and s'' for any diametral pitch, divide the figures given in the table opposite the required number of teeth, by the required diametral pitch.

Example: Find t'' and s'' for a gear 5 diametral pitch, 23 teeth.

$$1.5696 \div 5 = .3139 = t''.$$

$$1.0268 \div 5 = .2054 = s''.$$

To obtain t'' and s'' for any circular pitch, multiply the figures given in the table opposite the required number of teeth, by the addendum s (taking s from the Table of Tooth Parts, pages 321 and 322).

Example: Find t'' and s'' for a $\frac{3}{4}$ " circular pitch gear, 15 teeth.

$$1.5679 \times .2387 = .3743 = t''.$$

$$1.0411 \times .2387 = .2485 = s''.$$

If number of teeth required is not shown in table, take the nearest number of teeth.

An accurate and convenient tool for taking the measurements of gear teeth is shown in Fig. 62. With this gear tooth vernier, the distance from the top of the teeth to the pitch line, and thickness at the pitch line, can be accurately determined.

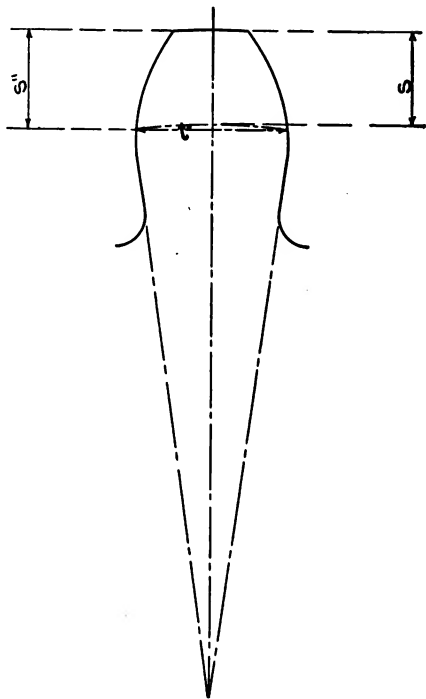


Fig. 61

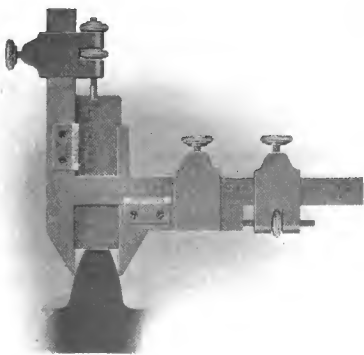


Fig. 62

Another tool, Vernier Caliper, No. 573, by use of which the bottom diameter of the teeth may be accurately measured to determine the depth of grooves, is shown in Fig. 63.

The depth of grooves may be ascertained when there are an even number of teeth by cutting two grooves opposite each other on the circumference of the blank and calipering the diameter from the bottom of the grooves, then computing the depth. When the number of teeth is uneven cut one groove and caliper the diameter from the bottom of the groove to the opposite side of the blank. In this last case be sure that the blank is of the correct diameter and runs true, otherwise the measurement will not be correct, unless allowance is made for these points.

Indexing. Indexing gear blanks is essentially the same as indexing any other work, and the instructions in Chapter IV are complete on



Fig. 63

this subject; therefore it is unnecessary to make any additional remarks here upon this point.

Cutting Two or More Gears Simultaneously. If the holes in the blanks are straight, and the hubs do not project beyond the face, a number of blanks may be fastened together on a gang arbor and several gears cut at a time. Care should be taken, however, if this is done, to see that the sides of the blanks are exactly parallel, otherwise when the arbor nut is clamped, the blanks will spring the arbor, causing it to run out and making it impossible to produce accurate gears.

Cutting Bevel Gears. The teeth of bevel gears constantly change in pitch from their large to small end, and for this reason it is impossible to cut gears whose tooth curves are theoretically correct, with rotary cutters having fixed curves, such as those used for cutting these gears on a milling machine. The cutter employed must be of a curve that will make the correct form at the large end of the tooth, hence it will necessarily leave the curve too straight at the small end. It is, therefore, the practice to cut the teeth as nearly correct as possible,

and then finish the gears by hand, filing the small ends of the teeth to get the correct curve.

Pitch of Bevel Gear. The pitch of a bevel gear is always considered as that at the largest end of the teeth.

Data Required to Cut Bevel Gears with Rotary Cutter. Pitch and number of teeth in each gear.

The whole depth of tooth spaces at both large and small ends of teeth.

The thickness of teeth at both ends.

The height of teeth above the pitch line at both ends.

The cutting angle; the angle to set spiral head on milling machine, and the proper cutter or cutters.

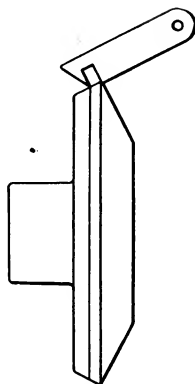


Fig. 64

Scratch Depth Line on Blank. Before placing the blank on machine, measure the length of face, angles and outside diameter of blank, and, if all dimensions are correct, place the blank on the arbor and fasten it securely in place; then scratch the whole depth of space at large end with a depth of gear tooth gauge similar to that shown in Fig. 64.

Selection of Cutter for Bevel Gears. The length of teeth or face on bevel gears is not ordinarily more than one-third the apex distance, Ab , Fig. 65, and cutters usually carried in stock are suitable for this face. If the face is longer than one-third the apex distance, special thin cutters must be made.

Rule for Selecting Cutter. Measure the back cone radius $a b$ for

N_a = No. of Teeth
in Gear
 N_b = No. of Teeth
in Pinion
 α = Centre Angle
of Gear

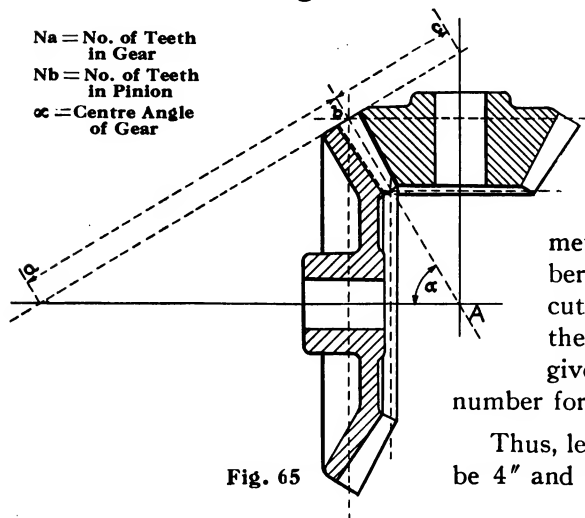


Fig. 65

the gear, or $b c$ for the pinion. This is equal to the radius of a spur gear, the number of teeth in which would determine the cutter to use. Hence twice $a b$ times the diametral pitch equals the number of teeth for which the cutter should be selected for the gear. Looking in the list given on page 149, the proper number for the cutter can be found.

Thus, let the back cone radius $a b$ be 4" and the diametral pitch be 8.

Twice four is 8, and 8×8 is 64, from which it can be seen that the cutter must be of Shape No. 2, as 64 is between 55 and 134, the range covered by a No. 2 cutter.

The number of teeth for which the cutter should be selected can also be found by the following formula:

$$\tan. \alpha = \frac{Na}{Nb}$$

$$\text{No. of teeth to select cutter for gear} = \frac{Na}{\cos. \alpha}$$

$$\text{No. of teeth to select cutter for pinion} = \frac{Nb}{\sin. \alpha}$$

If the gears are mitres or are alike, only one cutter is needed; if one gear is larger than the other, two may be needed.

Setting Cutter out of Centre. As the cutter cannot be any thicker than the width of space at small end of teeth, it is necessary to set it out of centre and rotate the blank to make the spaces of the right width at the large end of the teeth.

The amount to set cutter out of centre can be calculated with the table on page 326 and the following formula:

$$\text{Set-over} = \frac{Tc}{2} - \frac{\text{factor from table}}{P}$$

P = diametral pitch of gear to be cut.

Tc = thickness of cutter used, measured at pitch line.

Given as a rule, this would read: Find the factor in the table corresponding to the number of the cutter used and to the ratio of apex distance to width of face; divide this factor by the diametral pitch and subtract the quotient from half of the thickness of the cutter at the pitch line.

As an illustration of the use of this table in obtaining the set-over, take the following example: A bevel gear of 24 teeth, 6 pitch, 30 degrees pitch cone angle and $1\frac{1}{4}$ " face. These dimensions call for a No. 4 cutter and an apex distance of 4 inches.

In order to get the factor from the table, the ratio of apex distance with length of face must be known. This ratio is $\frac{4}{1.25} = \frac{3.2}{1}$, or about $\frac{3\frac{1}{4}}{1}$. The factor in the table for this ratio with a No. 4 cutter is 0.280. Next, measure the cutter at the pitch line. To do this, refer to the regular "Table of Tooth Parts" on pages 323 and 324, and get the depth of space below pitch line $s + f$. This depth of space below pitch line can also be found by dividing 1.157 by the diametral

pitch. In the case of 6 pitch $s + f = 0.1928$ inch. The thickness of the cutter at the pitch line is then found to be 0.1745 inch. This dimension will vary with different cutters, and will vary in the same cutter as it is ground away, since formed bevel gear cutters are commonly provided with side relief. Substituting these values in the formula, the following result is obtained:

Set-over = $\frac{0.1745}{2} - \frac{0.280}{6} = 0.0406$ inch, which is the required dimension.

After selecting a cutter and determining how much to set it out of centre, proceed as follows:

Set the cutter central with the spiral head or universal index head spindle, as the machine may be equipped.

Set the head to the proper cutting angle.

Set the index head for the number of teeth to be cut, placing the sector on the straight row of holes that are numbered to start with.

Set the dial on the cross feed screw to the zero line.

Scratch the depth of both the large and small end of the tooth to be cut in the blank.

Index and cut two or three grooves or centre cuts to conform to the lines in depth.

Set the cutter out of centre the trial distance, according to the formula on the previous page, by moving the saddle and noting adjustment on the cross feed screw dial.

Rotate the gear in the opposite direction from that in which the table is moved off centre (Fig. 66), until the side of the cutter nearest the centre line of the gear will cut the entire surfaces of the approaching sides of the teeth.

After making one or more cuts in accordance with this setting, move the table the same distance on the opposite side of the centre and rotate the gear in the opposite direction from that in which the table is moved until the cutter just touches the side of a tooth at the small end and cuts the entire surface of this side the same as the other.

Cut one or more spaces and measure the teeth at both large and small ends, either with a gear tooth vernier or with gauges made from thin pieces of metal and having a slot cut to give the correct depth and width at the pitch line.

If the teeth at the large end are too thick when the small end is correct, the amount to set the table out of centre must be increased. On the other hand, if the small end is too thick when the large end is

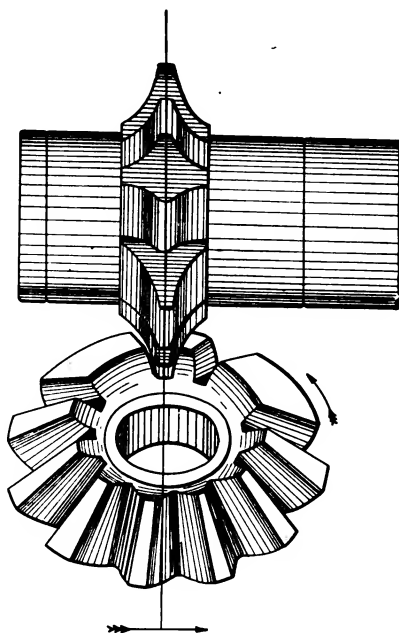


TABLE MOVED IN THIS DIRECTION
FOR THIS CUT.

Fig. 66

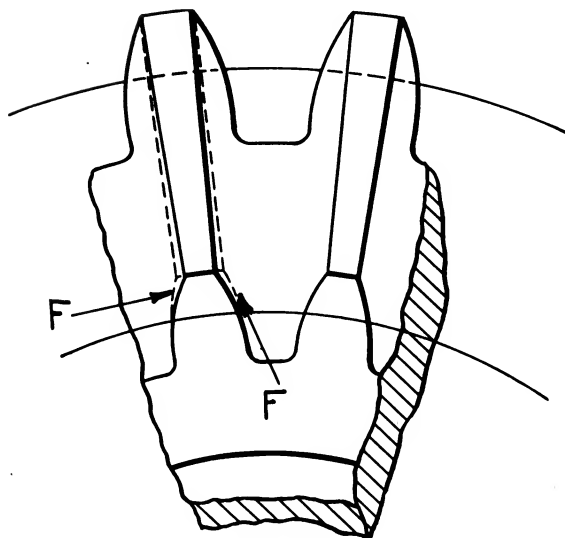


Fig. 67

correct, the amount the table is set out of centre is too great. In either case, the settings must be changed, and the operations of cutting repeated, remembering that the blank must be rotated and the table moved the same amount each side of centre, otherwise the teeth will not be central. It is well to bear in mind that too much out of centre leaves the small end proportionately too thick, and too little out of centre leaves the small end too thin.

The adjustment of the cutter and the rotating of the blank are shown in Fig. 66, which shows the setting, so that the right side of cutter will trim the left side of tooth and widen the large end of the space. The table has been moved to the right and the blank brought to the position shown, by rotating it in the direction of the arrow; the first out of centre cut was taken when the cutter was set on the other side of the centre.

After determining the proper amount to set cutter out of centre, the teeth can be finished, without making a central cut, by cutting round the blank with the cutter set out of centre, first on one side and then on the other.

To prevent the teeth being too thin at either end, it is important, after cutting once around the blank with cutter out of centre, to give careful attention to the rotative adjustment of the gear blank, when setting the cutter for trimming the opposite sides of the teeth. If by measurement, both ends are a little too thick, but proportionately right, rotate the gear blank and make trial cuts until one tooth is of the correct thickness at both ends. The cutting can then be continued until the gear is finished. Teeth of incorrect thickness may be more objectionable than a slight variation in depth.

The finished spaces, or teeth, as already mentioned, are of the correct form at the larger ends, and the teeth are of the correct thickness their entire length, but the tops of the teeth at the small ends are not rounded over enough. It is, therefore, generally necessary to file the faces of the teeth slightly above the pitch line at the small ends, as indicated by the dotted lines F F, Fig. 67. In filing the teeth, they should not be reduced any in thickness at or below the pitch line.

When cutting cast iron gears coarser than five diametral pitch, it is best to make one central cut entirely around the blank before attempting to find the correct setting of the cutter or rotation of the blank for correct thickness of teeth; and it is generally advantageous to take a central cut on nearly all bevel gears of steel.

Cutting Spiral Gears. In Chapter IV, we have gone into the subject of cutting spirals thoroughly, and, inasmuch as spiral gears are essentially cylinders having a succession of spiral grooves evenly spaced on their periphery, many of the points we have treated apply equally well to cutting them.

An important point in cutting these gears is the selection of the proper cutters to use. It is impossible to give in concise form any set of rules for doing this that will be readily understood, and anyone who desires to cut spiral gears, should make a far more complete study of the subject of spiral gearing than we can possibly give in this book. It is treated upon in our "Practical Treatise on Gearing," and "Formulas in Gearing," both of which books are extremely useful to the practical workman.

One point that it is well to remember is that in calculating spirals, the angle should be figured as that at the pitch line of the teeth, and not that on the surface or periphery of a gear.

Spirals of any angle to 45° can be cut on all of our universal milling machines with the cutter mounted in the regular way, and the swivel table swung to the proper angle, while those of an angle up to 55° with the axis, can be cut in some of our universal machines. If, however, the required angle is greater than that to which the table can be set, a vertical spindle milling attachment is required, and the adjustment for the cutting angle is then done with the attachment.

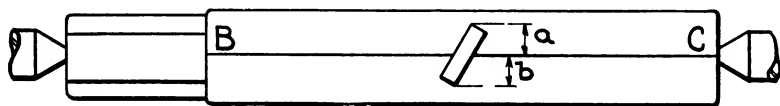


Fig. 68

To Set Cutter Central. It is essential that the cutter be set central with the work centres, and it may be done as follows: First, set the table, or attachment, in case the latter is used, to the correct cutting angle. Take a trial piece, Fig. 68, which is simply a cylindrical piece with centre holes in the ends, and mount it on the work centres, dogging it to the spiral head spindle. Draw, or scratch the line B C on the side of the arbor at the exact height of the work centres, and then revolve the arbor one-quarter of a turn by means of the index crank; that is, bring the mark B C exactly on the top of the piece. Now, start the machine and raise the knee until a gash is cut on the top of the piece. This gash shows the position of the cutter, and if a and

b are equal, the cutter is centred with the trial piece, which will, of course, bring it central with the work.

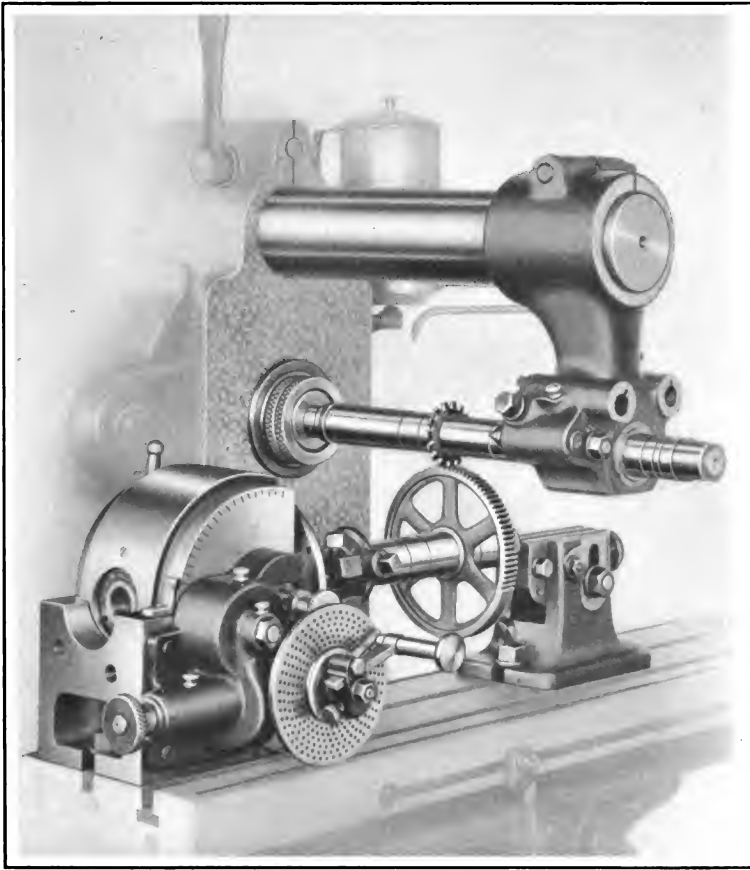
The same method is employed when using a vertical spindle milling attachment, except the scratched line is left at the side of the piece where it is at the exact height of the centres. The gash is then cut and examined as described above.

Test Settings and Index Gears. Before cutting a blank, it is well to raise the knee until the cutter will just make a slight trace on the work to see if the lead obtained by the change gears is correct. If the material in the gear blank is expensive, it is sometimes advisable to make a cast iron blank to experiment with before cutting into the expensive material.

Fastening Blanks. Spiral gears are more liable to slip in cutting than spur gears. Small blanks may be dogged to the spindle, but the dog must be far enough from the blank so that it will not interfere with the cutter. For blanks that are more than three or four inches in diameter, it is better to use a taper shank arbor held directly in the spindle; and for still heavier work, the arbor may be drawn into the spindle with a threaded rod.

Cutting Teeth. In cutting the teeth, either the cutter should be stopped after cutting each groove and positioned so that the teeth will not scrape the sides and bottom of the groove, the table being returned by hand; or the knee should be dropped so that cutter will clear the groove just cut, and then run the table back to the starting point. Most mechanics prefer to stop the machine, for in dropping the knee, there is more liability of error, as the depth of cut has to be set for each groove, and this also takes more time than it does to stop the machine.

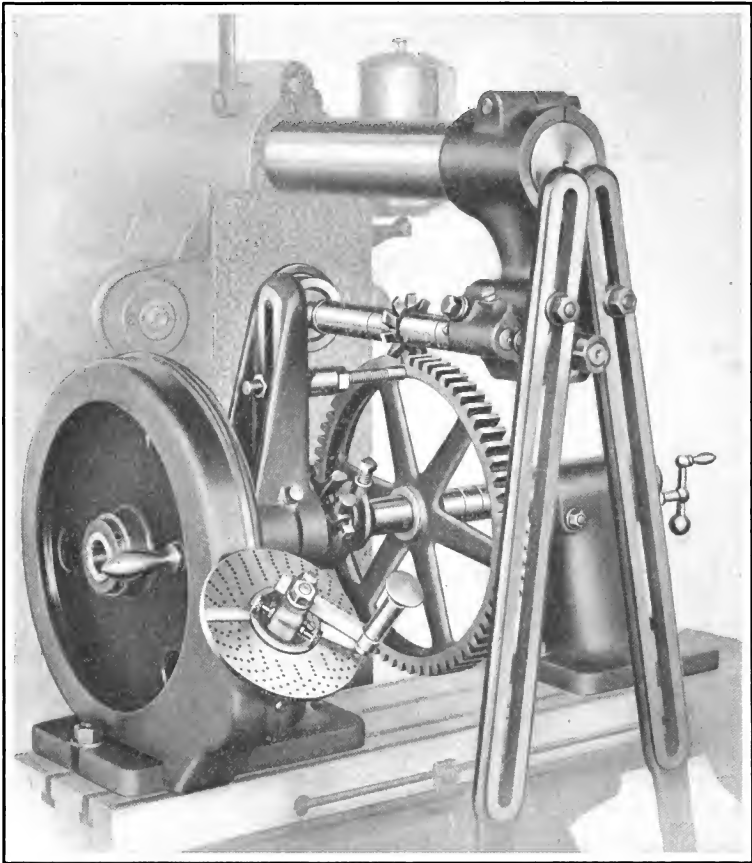
The remaining pages of this chapter are devoted to illustrations and descriptive data of gear cutting and similar operations on milling machines. These operations show how different gear cutting jobs can be set up, and are given simply as suggestions for those not familiar with this class of work.



Cutting a Spur Gear, Using the Spiral Head

Cutting a spur gear on a milling machine is a comparatively simple operation, as can be seen from the illustration. No special rigging whatsoever is required. The blank in this case is fastened on an ordinary lathe arbor mounted on the centres and dogged to the spiral head spindle.

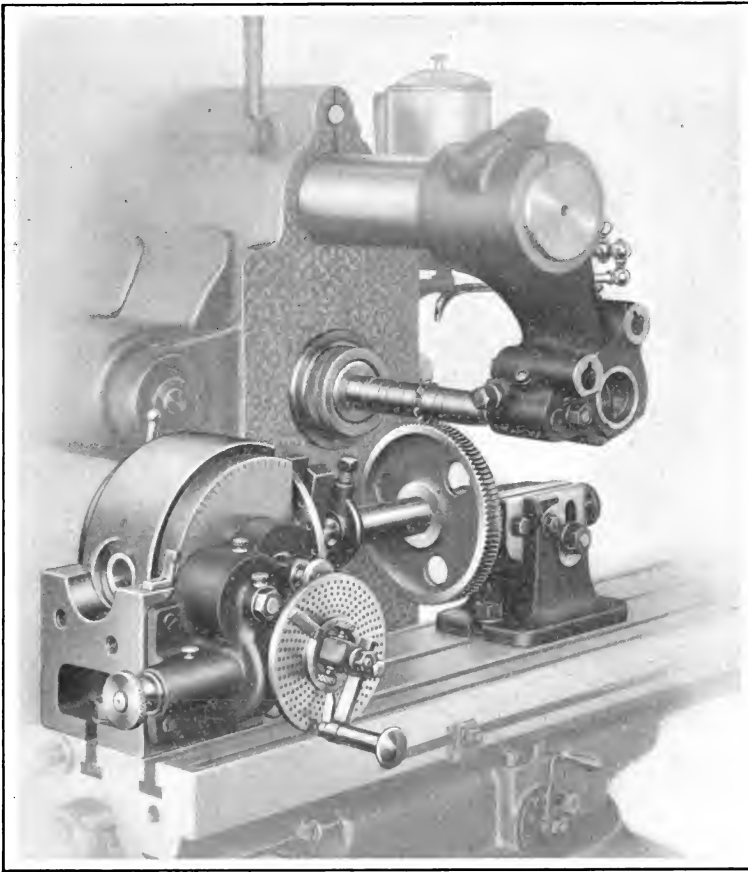
In commercial manufacturing, gears such as that shown would be produced in quantities on automatic gear cutting machines, but where only an occasional gear is wanted, such as in replacing a broken one, it is advantageous to cut it on a milling machine. A new gear for a machine can usually be secured in this manner far quicker than it can be ordered and delivered.



Cutting a Large Spur Gear, Using Gear Cutting Attachment

This operation shows the use of the gear cutting attachment described in Chapter V. The gear being cut is too large to be accommodated by the spiral head centres without using raising blocks, and then the results are not as satisfactory as can be gained by using this attachment.

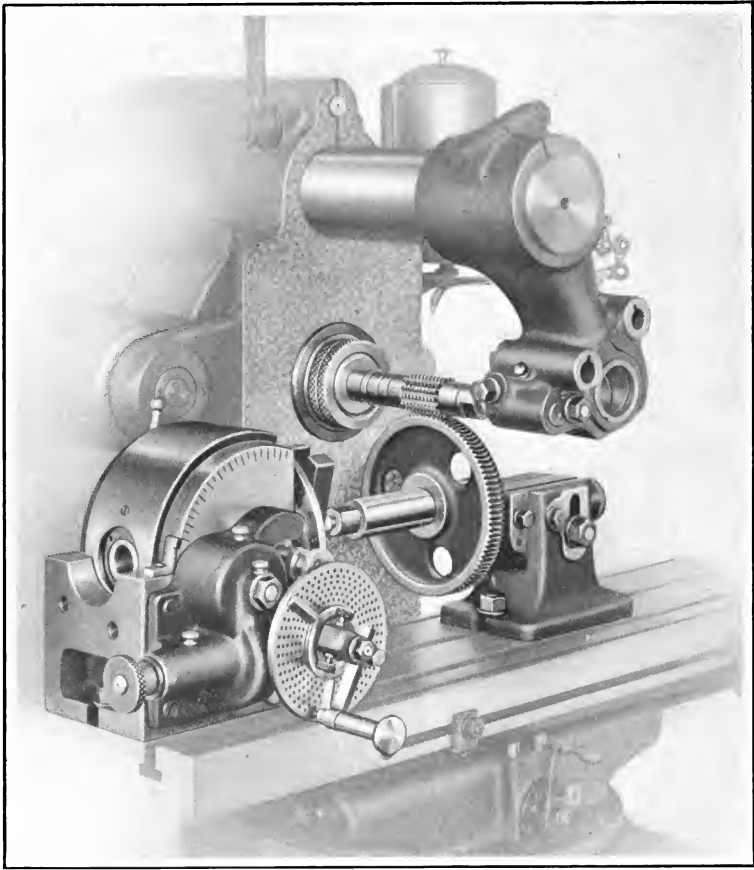
The gear is supported similarly to that on the opposite page. The advantage of a rim rest is illustrated, and it should also be noted that where the cut is as heavy as that shown, it is advisable to use the arm braces to give added stiffness to the cutter arbor. The table is fed from left to right, or so that the cut is against the rim rest.



Gashing Teeth in Worm Wheel

Finishing a worm wheel on a milling machine requires two separate operations. First, the operation of gashing the teeth, shown above, is performed; and then the teeth are hobbled, as shown in the illustration on page 164.

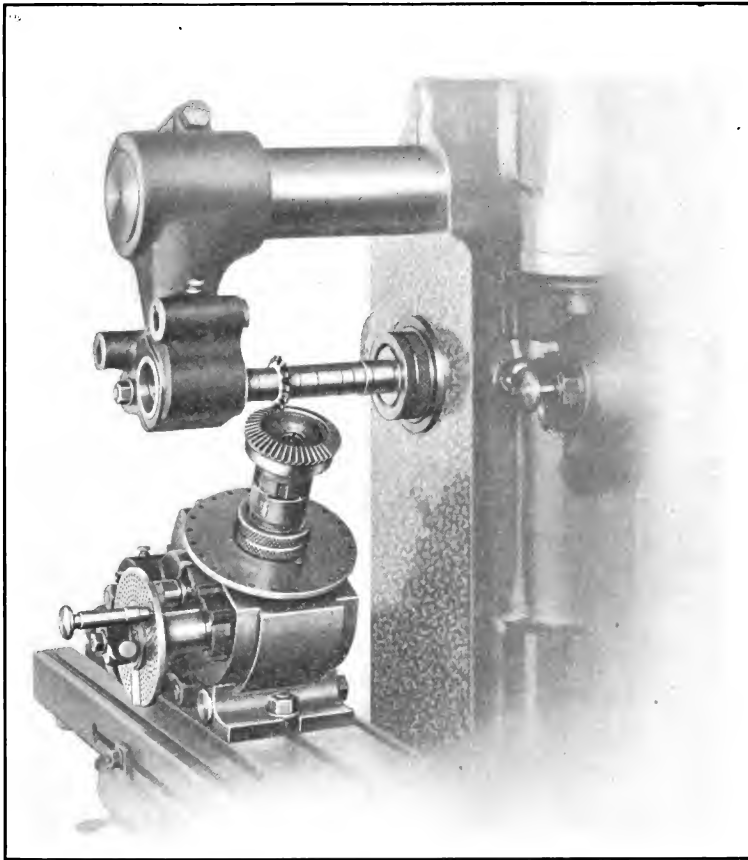
In gashing the teeth, the blank is dogged to the spiral head spindle, and the swivel table is swung to the required angle. The vertical feed is used and the teeth are indexed the same as in cutting a spur gear. Most of the stock is removed in gashing, only enough being left to allow the hob to take a light finishing cut.



Hobbing Teeth in Worm Wheel

The work is set up practically the same as in the operation of gashing the teeth, only the dog on the arbor is removed and the swivel table is set at zero. The worm wheel revolves freely on the centres, being rotated by the hob.

The wheel can be hobbled to the right depth by using a steel rule at the back of the knee to measure a distance equal to the centre distance of the worm and wheel from a line marked "Centre," on the vertical slide to the top of the knee. This line on the vertical slide indicates the position of the top of the knee when the index centres are at the same height as the centre of the machine spindle.

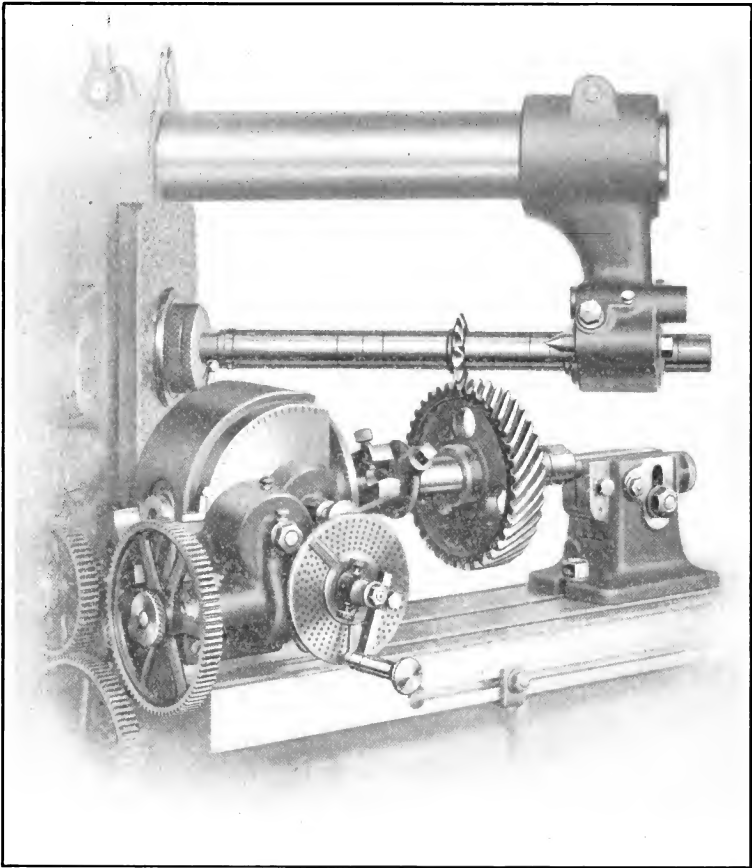


Cutting Teeth in Bevel Gear

The illustration on this page shows a milling machine set up for cutting the teeth of a bevel gear.

The gear is held in place by a split bushing that is expanded in the hole. The spiral head is elevated to the proper cutting angle and the table is fed longitudinally from left to right.

In setting off centre to trim the sides of the teeth to the proper thickness, the table is adjusted the required amount on the knee and then the blank is rotated by means of the index crank, as previously explained.

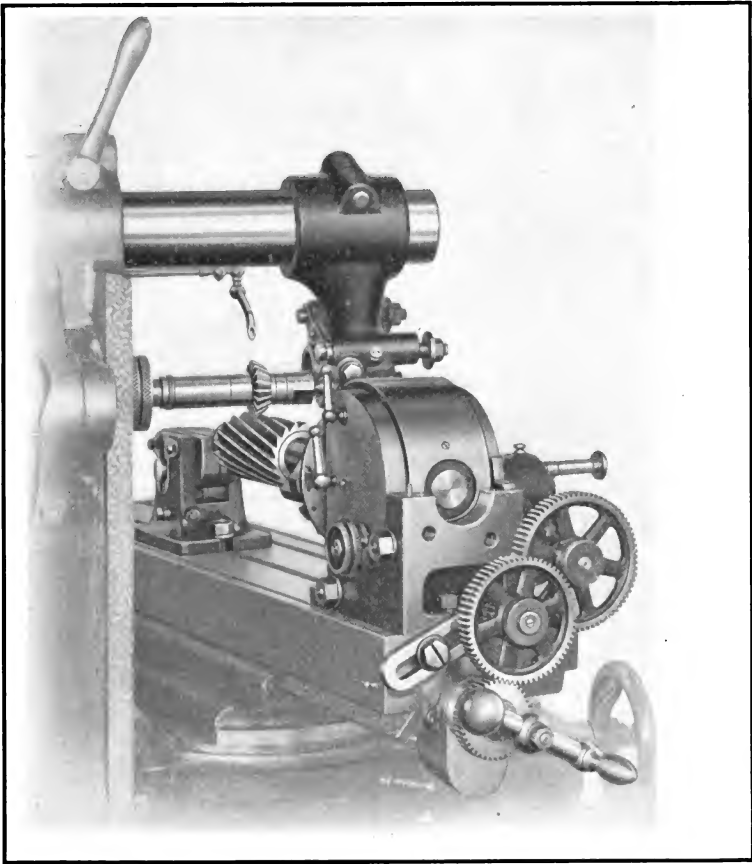


Cutting Teeth in Spiral Gear

The machine is shown, in the illustration above, set in position to cut a left-hand spiral gear of 45° angle.

The gear is mounted in the same manner as in several previous operations, but instead of remaining stationary as the table advances, it is rotated by means of the required change gears to give the correct lead to the teeth. The table is fed longitudinally from left to right.

A right-hand spiral gear of the same angle may be cut in the same manner by setting the table to 45° the other side of zero and leaving out the intermediate or reverse gear.

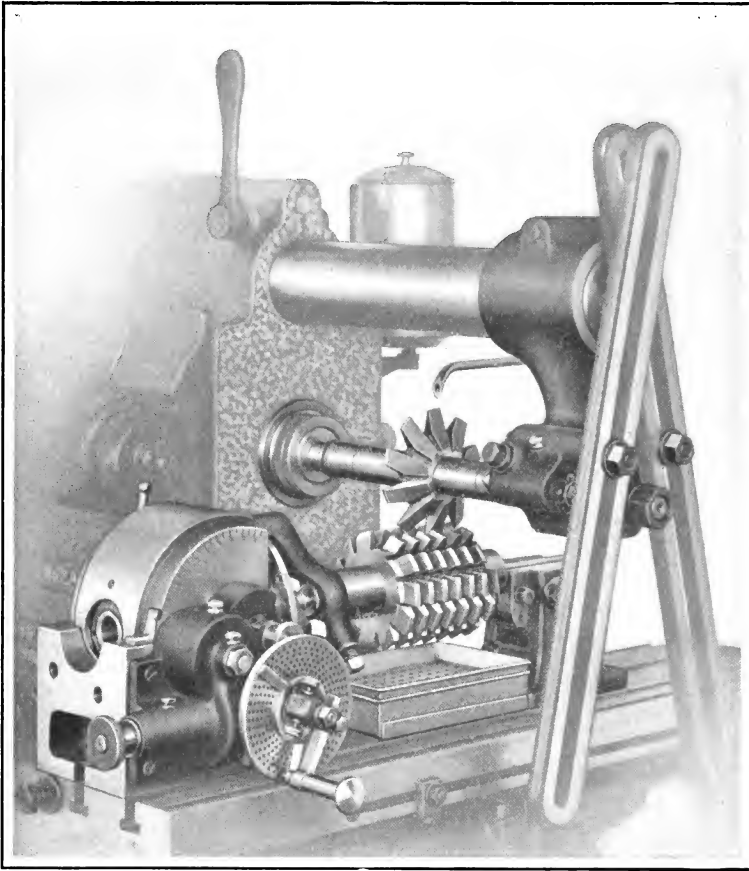


Cutting Spiral Teeth in Milling Cutter

This operation shows the arrangement for cutting teeth in a right-hand spiral milling cutter.

The work is 6 inches long and 3 inches in diameter, and an angular cutter 3 inches in diameter is employed. An angle of $11\frac{1}{4}^{\circ}$ is desired, and the saddle is accordingly set to that angle and the head is geared to give a lead of 48".

The work is mounted on an arbor that is dogged to the spiral head spindle, and care is taken that there is no lost motion between the spindle and work.

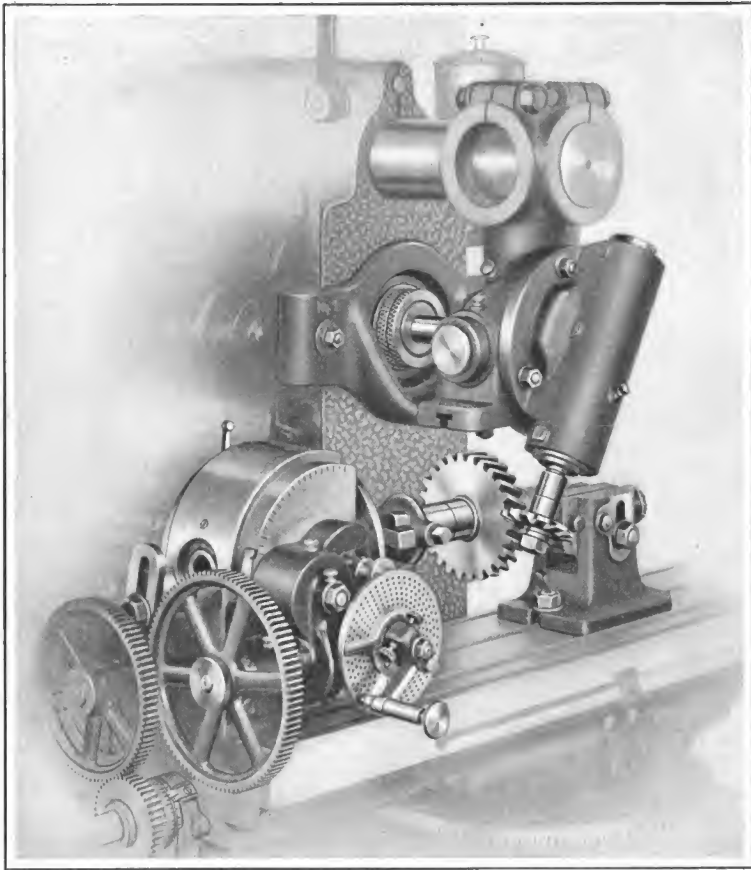


Gashing a Hob

While this is not strictly a gear cutting operation, it is set up and performed in practically the same manner, the principal difference being in the shape of cutter used. Many hobs are gashed spirally, and this is done in a similar way to cutting the teeth in a spiral gear.

In this operation, the cut is heavy and it is advisable to use arm braces, so that a coarser feed can be employed and the work done more quickly.

The table is fed longitudinally from left to right. Oil is used on the cutter and is collected and strained in the pan below the work. An oil pump equipment can be used to good advantage on such jobs.

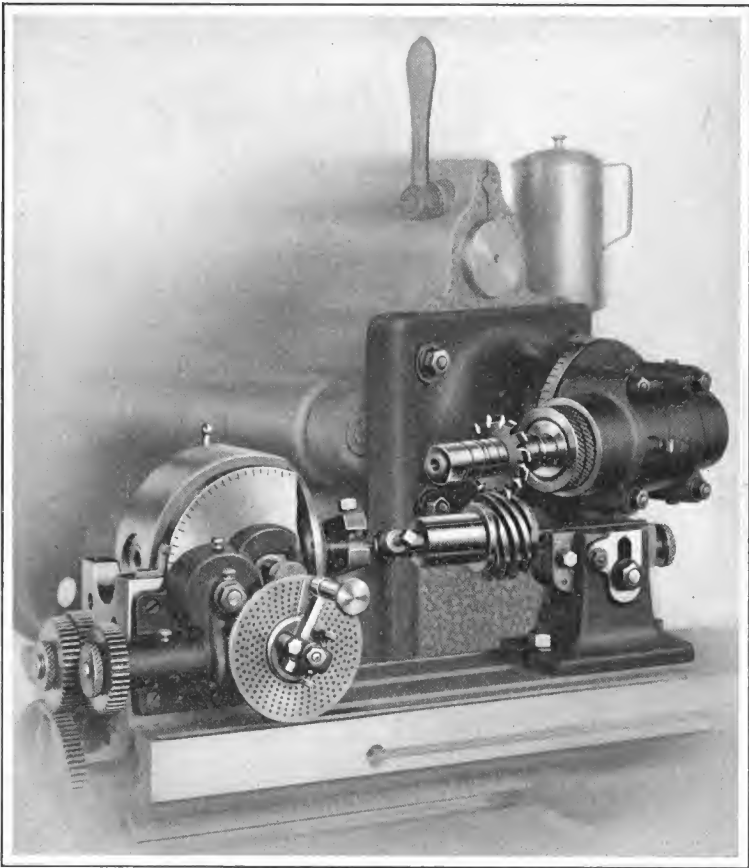


Cutting Teeth in Spiral Gear, Using Compound Vertical Spindle Milling Attachment

This operation shows the use of a compound vertical spindle milling attachment in cutting a spiral gear.

It will be noticed that where this attachment is used, the swivel table is set at zero and the angle of the spiral obtained by swinging the head of the attachment. The cutting is also done on the side, instead of the top of the gear.

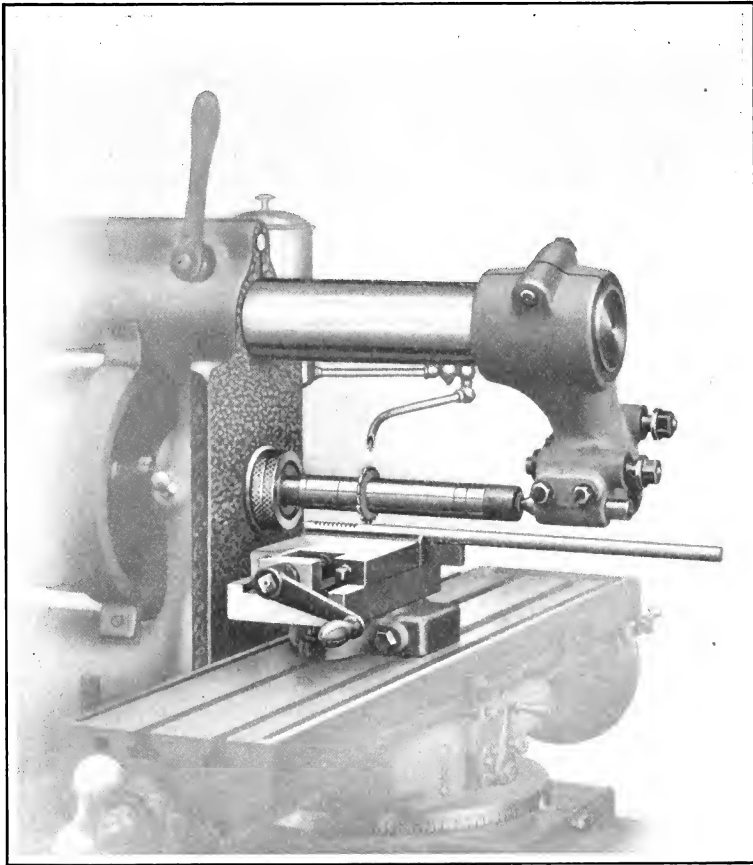
In cutting left-hand spirals, the cutter would be at the back of the blank, the head of the attachment swung to the other side of zero, and an intermediate gear would be introduced in the train to reverse the direction of rotation.



**Cutting a Short Lead Spiral Gear, Using a
Vertical Spindle Milling Attachment**

When the table cannot be swung to the required angle, a vertical spindle attachment may be used. The attachment is swung 90° up from zero, and the required angle of the spiral is then obtained by the swivel table.

Where the lead is as short as that above, it is better to employ the special attachment shown in Chapter V, for the ratio of gearing of the spiral head is such that severe stresses are brought to bear upon it in feeding the work. If, however, the job is set up as above, it is necessary to feed the work by hand.

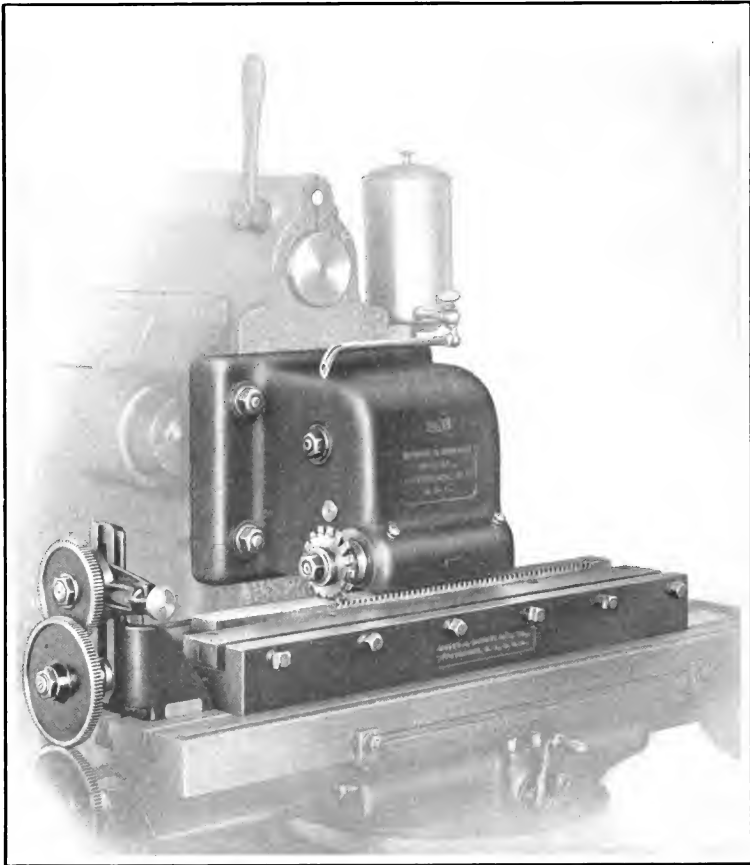


Milling Rack Teeth in Cylindrical Shaft

Sometimes it is required to mill a few rack teeth in a cylindrical shaft or plunger, and where a rack cutting attachment is at hand, this can be readily done. If one is not convenient, however, the work can be done in the manner shown above.

The shaft is supported on a parallel and clamped in a vise, and the teeth are indexed by means of the graduated dial on the cross feed screw.

Before indexing, care should be taken to remove backlash from the screw.

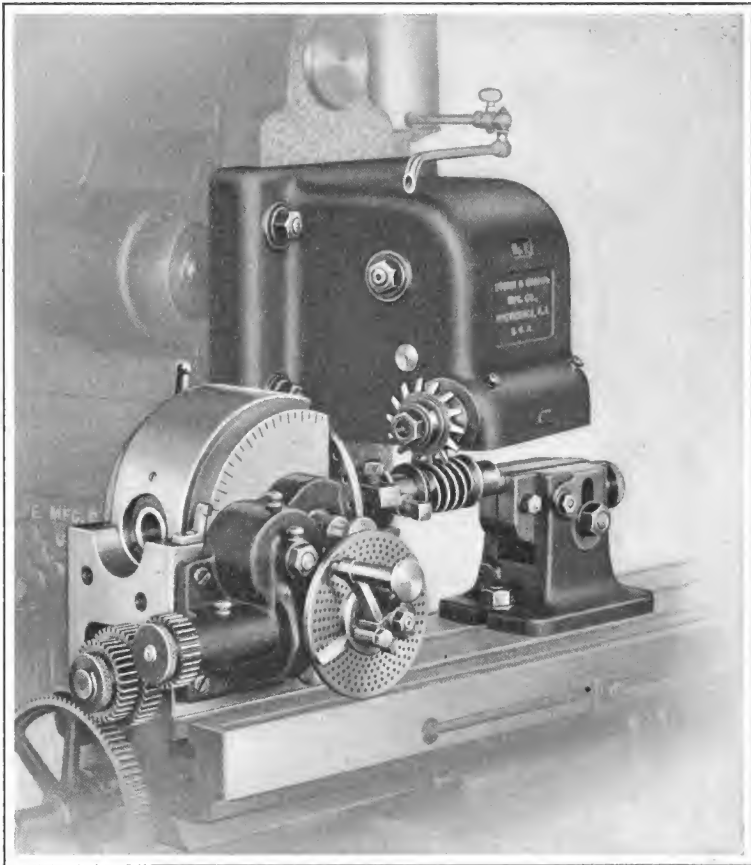


**Cutting Teeth in Rack, Using Rack Cutting and
Indexing Attachments**

The method of cutting a steel rack, using the rack cutting and indexing attachments described in Chapter V, is clearly shown in this illustration.

The rack is fastened in the vise of the attachment, and the teeth are indexed by the indexing attachment.

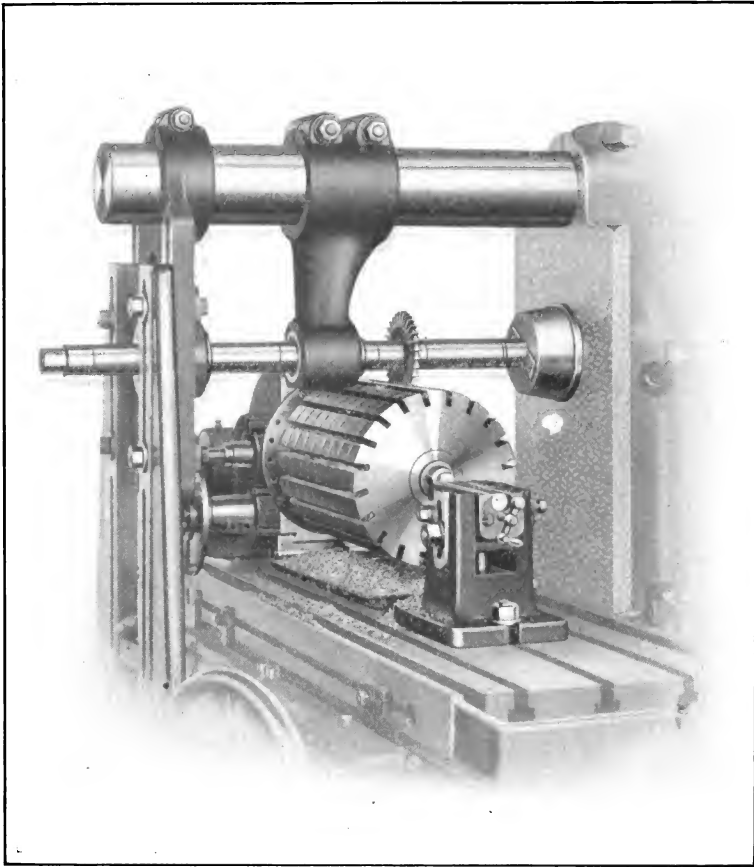
The automatic transverse table feed is used and the direction of cut is from the back of the rack toward the front, that is, against the direction in which the cutter rotates. Oil is used as a lubricant.



Cutting a Worm Thread, Using Rack Cutting Attachment

Another use of the rack cutting attachment on a universal milling machine is illustrated in this operation. It is especially serviceable for cutting short lead spiral gears, when the angle is such that they cannot be cut on the milling machine in the usual way. An advantage of the rack cutting attachment over the vertical spindle milling attachment for this purpose is that work of smaller diameter can be accommodated, or a smaller cutter can be used.

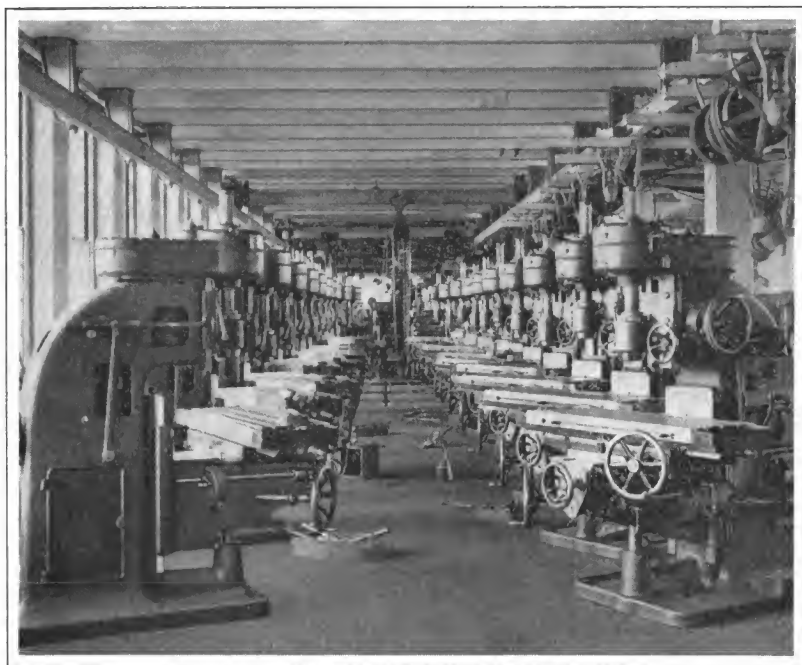
The cutting is done on the top of the work, and oil may be led to the cutter from the can shown.



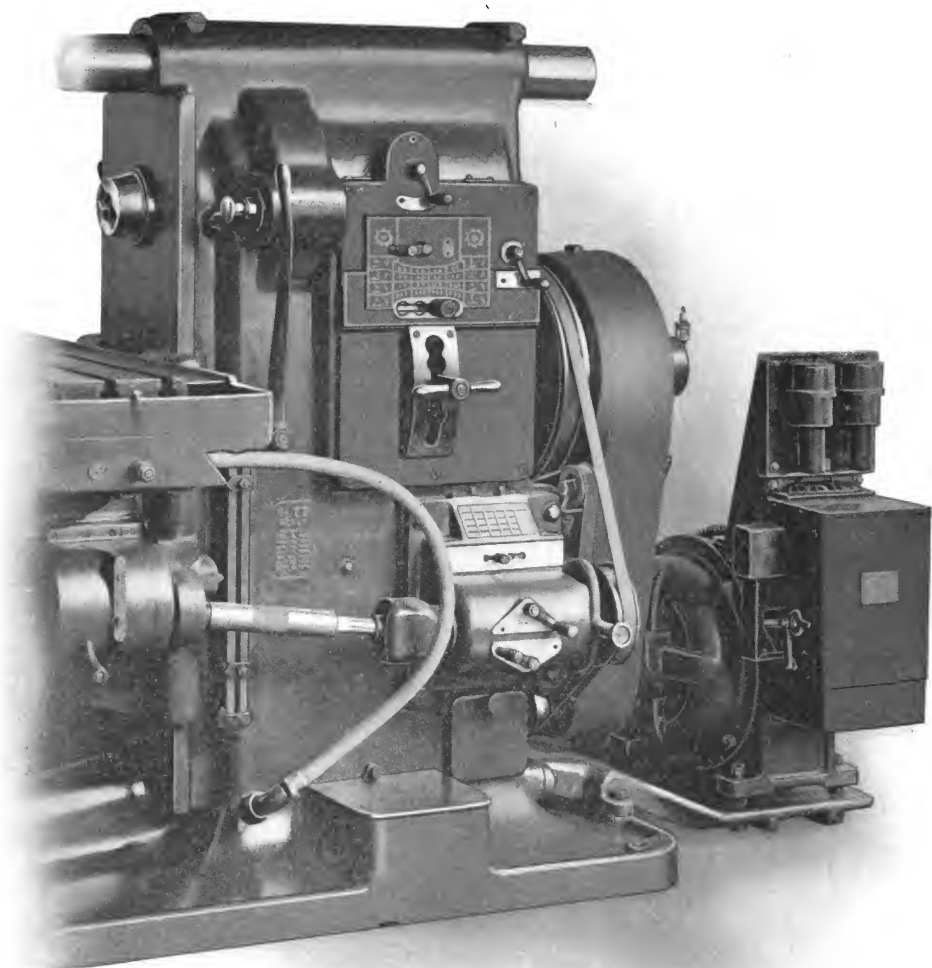
Cutting Blade Grooves in Bodies of Inserted Tooth Cutters

Nine of these steel cutter bodies are placed together on an arbor and clamped solidly by a nut at the end. The arbor is then driven into the spiral head spindle and the foot-stock is put in place. To give the proper rake to the front of the blades, the saddle is set so that the cutter does not come directly over the spiral head and foot-stock centres. As the number of grooves cut is 20, indexing can be conveniently accomplished with any index plate.

A side milling cutter 5 inches in diameter and $\frac{7}{8}$ " wide is used, and the grooves are cut to a depth of $\frac{7}{8}$ ".



**Sections of Milling Machine Departments in Our Works,
Showing Erecting of Machines in Large Lots**



**Constant Speed Drive Plain Milling Machine
fitted with Motor Drive**

CHAPTER IX

Milling Operations — Cam Cutting, Graduating and Miscellaneous Operations

Cam Cutting. Face, peripheral and cylindrical cams of all ordinary sizes can be cut upon a milling machine, and a far more satisfactory job can be obtained than is possible by drilling around the outline on a cam blank, breaking it off and then milling or filing to a line.

When it is required to cut several cams of the same outline at frequent intervals, it is an advantage to add the cam cutting attachment, illustrated and described in Chapter V, to the equipment of the machine. The formers that are required to produce the different cams can be preserved, and it is then only a matter of a few minutes' time to set up the machine to cut any number of cams for which a former is at hand.

Another method that is often followed, in cutting peripheral cams, especially those for use on automatic screw machines, is that of using the spiral head and a vertical spindle milling attachment. Illustrations of this are shown on pages 187 and 188. The spiral head is geared to the table feed screw, the same as in cutting ordinary spirals, and the cam blank is fastened to the end of the index spindle. An end mill is used in the vertical spindle milling attachment, which is set in each case to mill the periphery of the cam at right angles to its sides, or, in other words, the axes of the spiral head spindle and attachment spindle must always be parallel to mill cams according to this method. The cutting is done by the teeth on the periphery of the end mill. The principle of this method is as follows: Suppose the spiral head is elevated to 90° , or at exact right angles to the surface of the table (see Fig. 69), and is geared for any given lead. It is then apparent that, as the table advances and the blank is turned, the distance between the axes of the index spindle and attachment spindle becomes less. In other words, the cut becomes deeper and the radius of the cam is shortened, producing a spiral lobe, the lead of which is the same as that for which the machine is geared.

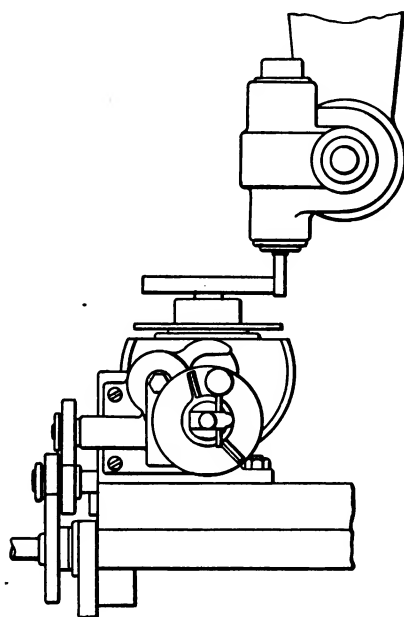


Fig. 69

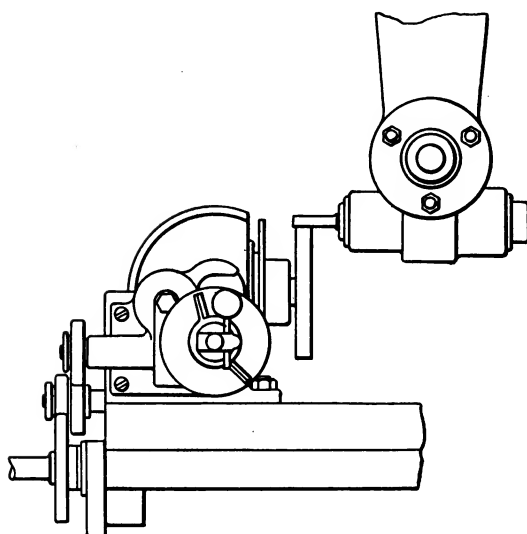


Fig. 70

Now, suppose the same gearing is retained and the spiral head is set at zero, or parallel to the surface of the table (see Fig. 70). It is apparent, also, that the axes of the index spindle and attachment spindle are parallel to one another. Therefore, as the table advances, and the blank is turned, the distance between the axes of the index spindle and attachment spindle remains the same. As a result, the periphery of the blank, if milled, is concentric or the lead is 0.

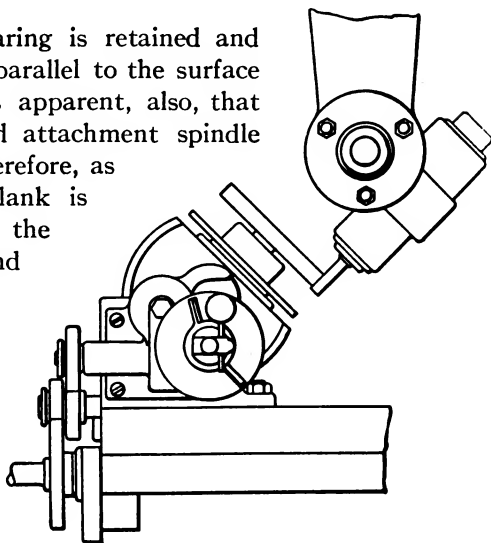


Fig. 71

If, then, the spiral head is elevated to any angle between zero and 90° (see Fig. 71), the amount of lead given to the cam will be between that for which the machine is geared and 0. Hence it is clear that cams with a very large range of different leads can be obtained with one set of change gears, and the problem of milling the lobes of a cam is reduced to a question of finding the angle at which to set the head to obtain any given lead.

In order to illustrate the method of obtaining the correct angle, drawings of two cams to be milled, and data connected with same, are given in Figs. 72 and 73.

It is first necessary to know the lead of the lobes of a cam, that is, the amount of rise of each lobe if continued the full circumference of the cam. This can be obtained from the drawings as follows: For cams where the face is divided into hundredths, as those shown: multiply 100 by the rise of the lobe in inches and divide by the number of hundredths of circumference occupied by the lobe. For cams that are figured in degrees of circumference: multiply 360 by the rise of the lobe in inches and divide by the number of degrees of circumference occupied by the lobe. Taking Fig. 72 for example, we have a cam of one lobe which extends through 91 hundredths of the circumference, and has a rise .178". Then $\frac{100 \times .178''}{91} = .1956$ lead of lobe, or .196", which is near enough for all practical purposes.

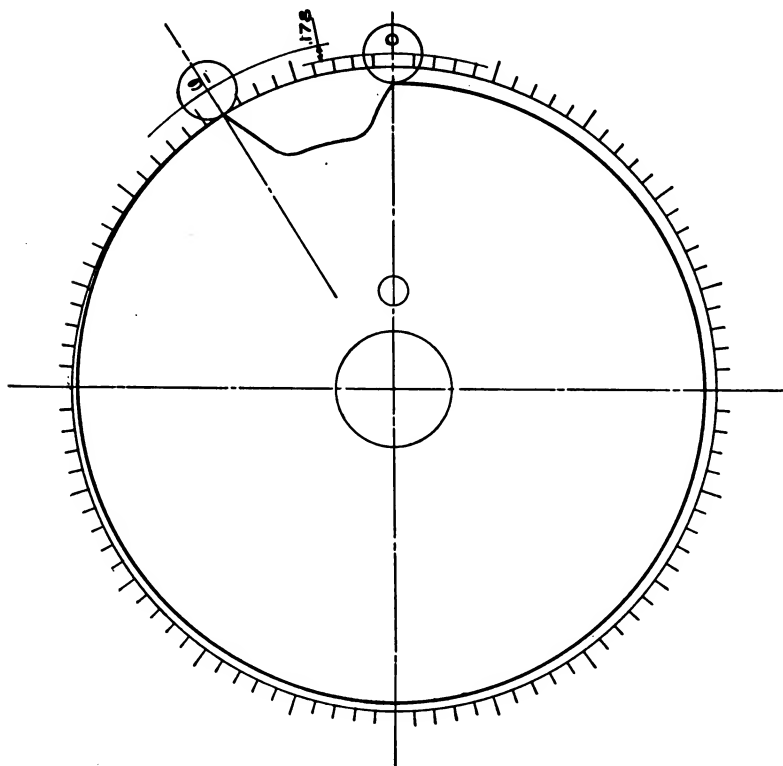


Fig. 72

As a .196" lead is much less than .67", which is the shortest lead* regularly obtainable on the milling machine, (see Table of Leads, pages 229 to 247), the change gears that will give a lead of .67" may be used, and then the angle of the head can be adjusted so that a lead of .196" will be obtained on the cam lobe with these change gears. The rule for this is:

Divide the given lead of the cam lobe by a lead obtainable on the machine, and the result is the sine of the angle at which to set the head.

Continuing the calculation for the lobe of the cam in Fig. 72, we therefore have: $\frac{.196}{.67} = .29253$

Hence, .29253 is the sine of the correct angle. Turning to the Table of sines and cosines on pages 300 to 308, we find that .29253 is very

*By the use of the short lead attachment illustrated and described in Chapter V, much shorter leads than .67" are obtainable.

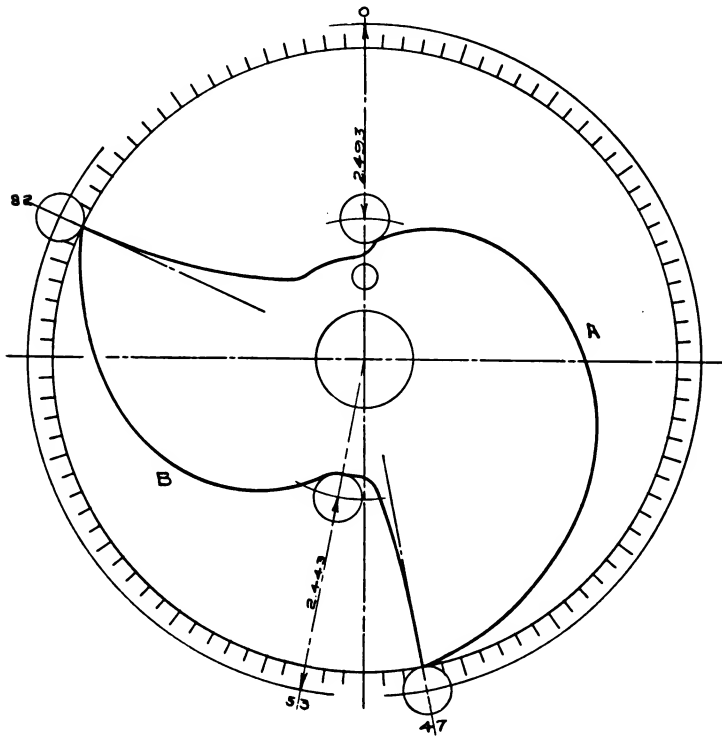


Fig. 73

near .29265, which is the sine of an angle of 17° and $1'$. As the spiral head is not graduated closer than quarter degrees, it will be satisfactory to elevate the head just a hair over 17° ; then, with the gearing for a lead of $.67''$, a cam with a lead of $.196''$ will be obtained.

The minute errors between the actual lead $.1956''$ and $.196''$, and in the sines and angles of this calculation can be safely ignored, as it is not possible in practice to work very much closer than we have outlined.

The portion of the periphery of the cam from 91 hundredths to zero, represents a clearance of the cutting tool prior to the beginning of the throw. It is usually milled to a line, or drilled, broken out, and filed.

In Fig. 73, we have a cam with two lobes, one, A, having a rise of $2.493''$ in 47 hundredths, and the other, B, having a rise of $2.443''$ in 29 hundredths. On cams such as this, where it is necessary to remove considerable stock, it is usually the practice to first outline

the approximate shape of the lobes on the blank and drill and break off the surplus stock.

Following the same method of figuring to find the lead of the lobes on this cam, we have: $\frac{100 \times 2.493''}{47} = 5.304''$ lead for lobe A, and $\frac{100 \times 2.443''}{29} = 8.424''$ lead for lobe B.

Where there are two or more lobes on a cam, the machine is geared for a lead slightly longer than the longest one required, which in this case is 8.424'', then the other lobes are milled without changing the gears. Referring to the Table of Leads, we find a lead of 8.437'', which is slightly larger than 8.424''. This gearing is, therefore, accepted, and it is required to find the sine of the angle at which to set the head for lobe B.

$\frac{8.424}{8.437} = .99846$ sine of angle at which to set head. Looking at a table of sines and cosines, .99846 is found to be the sine of an angle of 86° and 49'. The head is, therefore, set at a trifle over 86½°.

When lobe B has been milled, the head is set for lobe A.

$\frac{5.304}{8.437} = .62865$ sine of an angle at which to set head. Referring again to the table of sines and cosines, we find that .62865 is very near to .62864, which is the sine of an angle of 38° and 57'. The head is, therefore, set slightly under 39° for this lobe.

The other portions of the periphery of this cam are formed up either by filing to a line before the blank is put on the milling machine or by milling to the line after the lobes have been formed.

Whenever possible, the job should be set up so that the end mill will cut on the lower side of the blank, as this brings the mill and table nearer together and makes the job more rigid. It also prevents chips from accumulating, and enables the operator to better see any lines that may be laid out on the face of the cam.

When the lead of the machine is over 2 inches the automatic feed can be used, but when the lead is less than 2 inches the job should be fed by hand, with the index crank, as shown on page 187.

By the use of the calculations just given, we have compiled tables on pages 248 to 299 that give a wide range of leads from 0 to 20'' that can be obtained with the spiral head in the manner described. These tables will be found useful, as they give all data and settings without the necessity of figuring.

Graduating. Another use to which the milling machine may be put is that of graduating flat scales and verniers.* It is possible to obtain very accurate results, and when required, odd fractional divisions can be easily spaced.

This operation requires the use of the spiral head and a single pointed graduating tool which is held stationary in a fly cutter arbor, mounted directly in the spindle, or can be fastened to the spindle of a vertical milling or rack cutting attachment. The scale to be

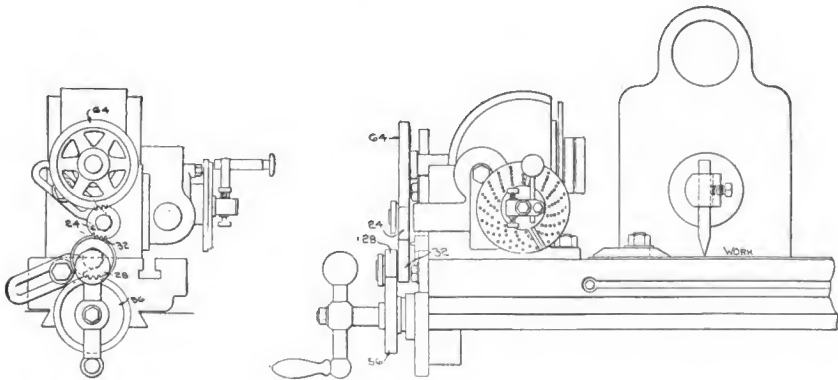


Fig. 74

graduated is clamped to the surface of the table parallel to the table T slots. No power is required for the operation, as the lines are cut by moving the table transversely under the point of the tool, and this can be easily done by hand. The spiral head spindle is equal-gearred to the table feed screw as shown in Fig. 74, and indexing for the divisions required is accomplished by means of the index plates, the index crank being turned in the usual manner for each division.

It has already been explained that one turn of the index crank moves the spiral head spindle $\frac{1}{40}$ of a revolution, and if equal gearing is employed between this spindle and the table feed screw, the feed screw will likewise make $\frac{1}{40}$ of a complete revolution. The lead of the feed screw being .25", it is apparent that one turn of the index crank will advance the table an amount equal to $.25" \times \frac{1}{40}$, or .00625".

Suppose it is required to graduate a scale with lines .0218" apart. Now, if one turn of the index crank moves the table a distance of

* A method of obtaining fine divisions on a circular plate is mentioned under Differential Indexing in Chapter IV.

.00625", it will take more than one turn to move the table a distance of .0218". Hence,

$$\frac{.02180}{.00625} = 3 \frac{.00305}{.00625}$$

Taking the remainder, .00305", and referring to the tables on pages 318 to 320, we find that it is very near .0030488, which is the distance the table will be moved by using the 41 hole circle in one of the index plates furnished and indexing 20 holes. The error between the actual remainder and the amount given in the table is so small that it can be safely ignored.

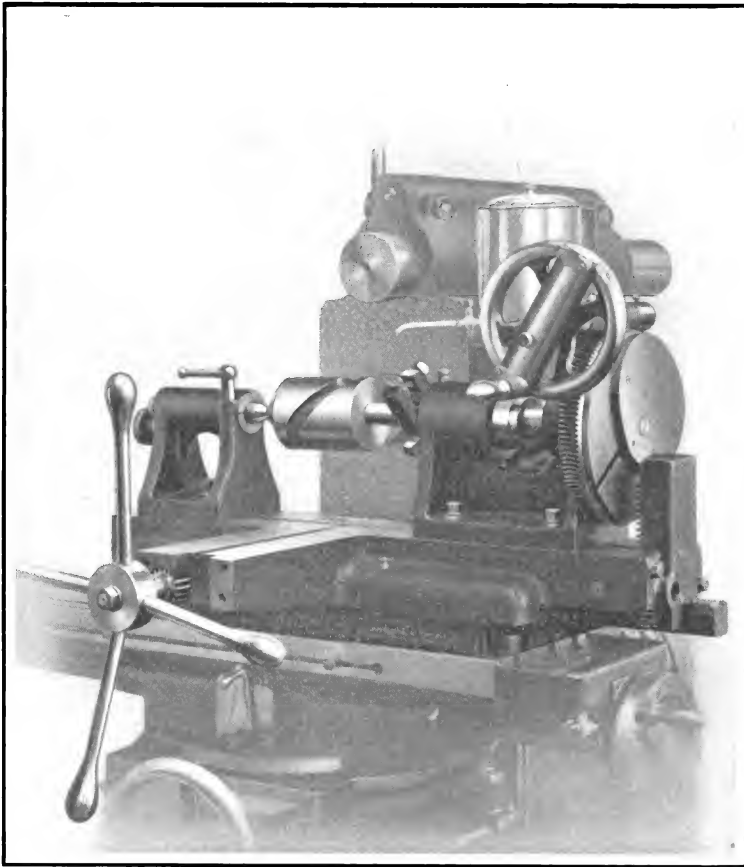
Therefore, to graduate a scale with divisions .0218 of an inch apart, an index plate having a 41 hole circle would be used and the crank would have to make three complete turns and then be advanced 20 holes in the 41 hole circle for each division.

It should be remembered in graduating that care must be exercised to prevent backlash between the index crank and table feed screw. To this end, the crank should always be turned in the same direction.

If required, the ratio of gearing between the spiral head spindle and the table feed screw can be changed, but this complicates the operation somewhat and should be resorted to only when it is impossible to get accurate enough results with the method described. Upon referring to the tables on pages 318 to 320 and noting the extreme fineness in divisions that it is possible to obtain, it is apparent that there is little occasion to change the ratio of gearing.

Accurate graduating can also be done by using scales and verniers such as illustrated and described in Chapter V.

Illustrations of cam cutting, and many miscellaneous milling operations will be found on the following pages, and a careful study of the cuts and descriptions may be of value to the reader.

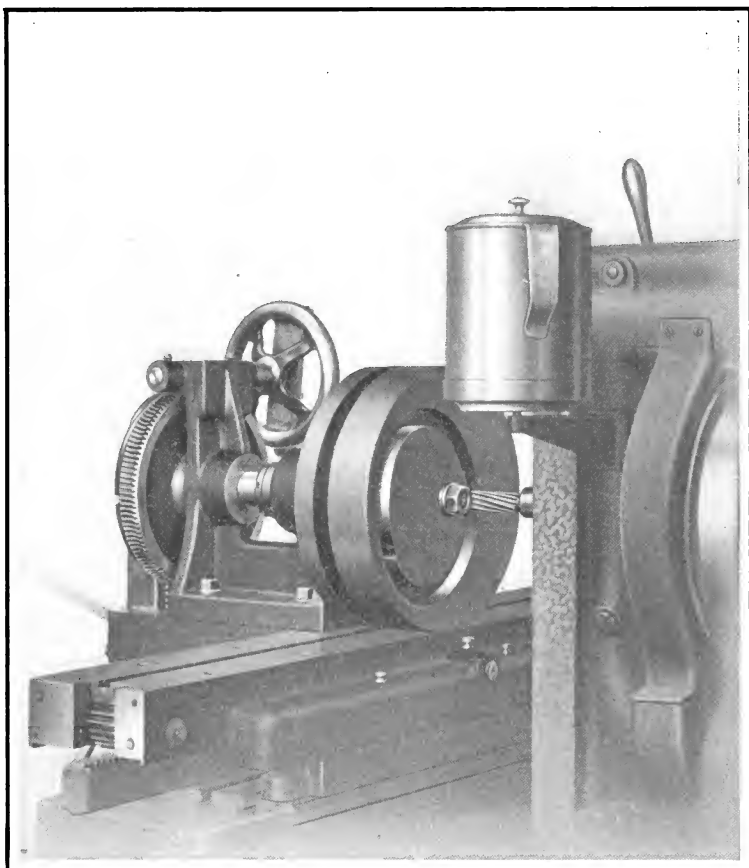


Cutting a Cylindrical Cam, Using Cam Cutting Attachment

For cutting a cylindrical cam, the head is bolted to the bed parallel to the table and the cam blank is supported on an arbor mounted on the attachment centres and dogged to the spindle. The table is raised to a point that brings the attachment centres at the same height as the axis of the spindle.

A spiral end mill is used for this operation and the necessary movement to feed the work is obtained from the attachment, the table remaining clamped in one position.

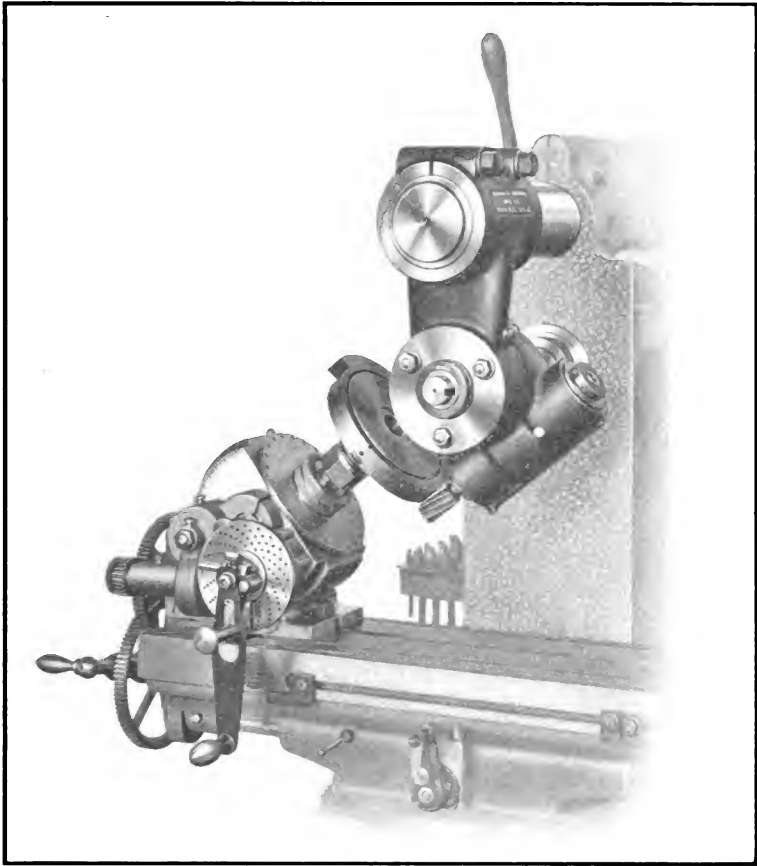
This view of the attachment shows very clearly the former on the outer end of the head.



Cutting a Face Cam, Using the Cam Cutting Attachment

In this operation the head of the attachment is bolted to the bed at right angles to the table and the cam blank is fastened to the attachment spindle by means of a bolt. A peripheral cam would be milled in the same manner. The necessary rotative movement is obtained by hand feed, and the longitudinal movement to give the proper lead and shape to the cam is produced by the cam former and the mechanism of the attachment, as described in Chapter V.

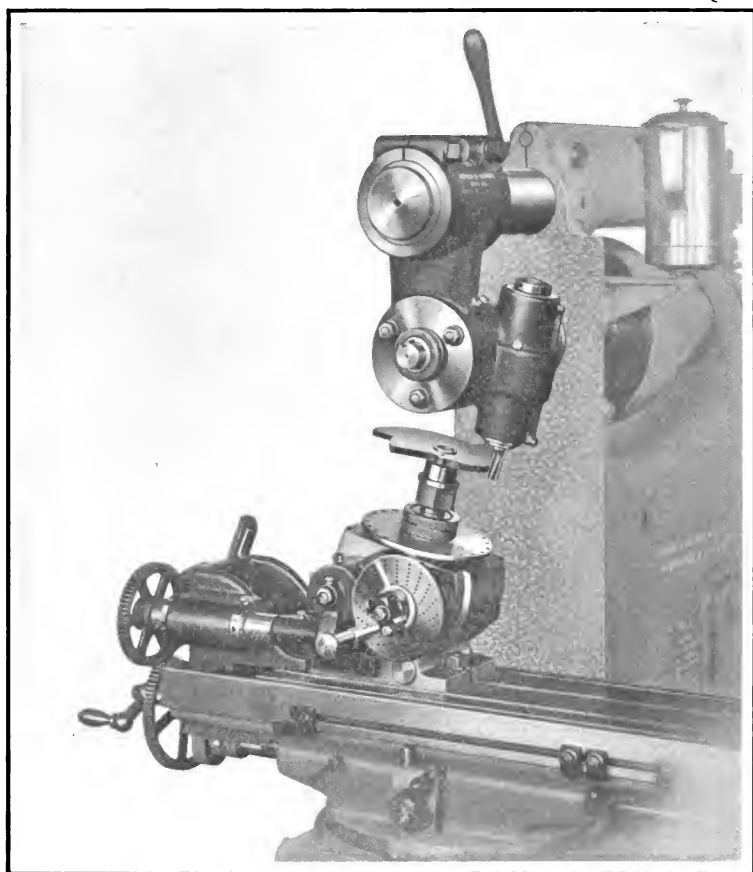
A spiral end mill is used. The machine table remains clamped in one position.



Milling a Cam, Using Spiral Head and Vertical Spindle Attachment

The cam blank is mounted on an expansion arbor inserted in the taper hole of the spiral head spindle.

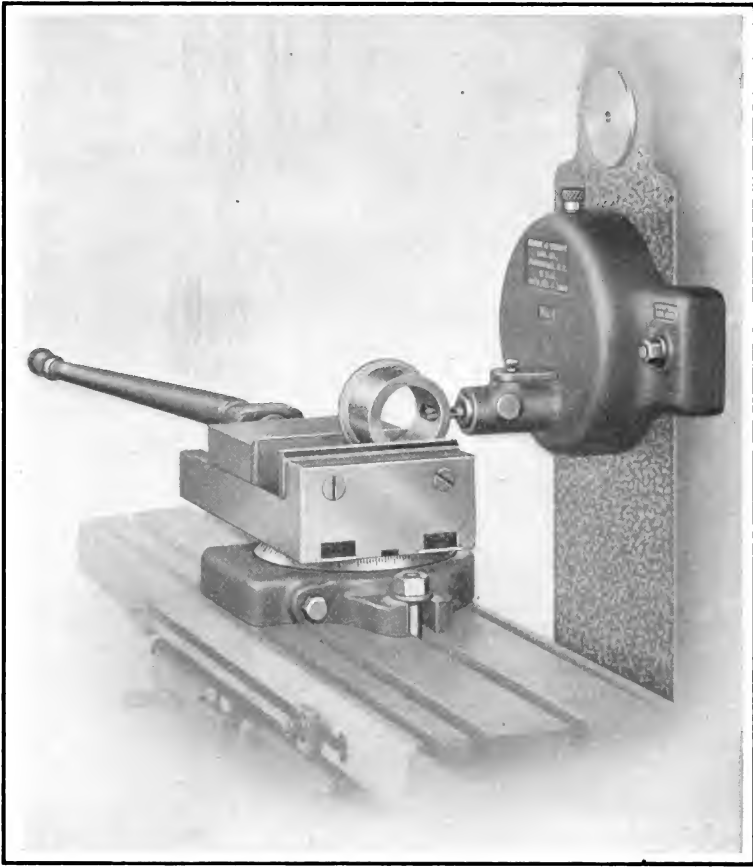
Suitable change gears are selected to give the approximate lead and the spiral head is elevated to obtain the exact lead; the vertical attachment is then set to bring the end mill parallel with the axis of the cam. Where such short leads as this are being milled, there is great stress brought upon the spiral head gearing in attempting to use the automatic feed. For this reason the extended crank is fastened over the regular index crank and the job is fed by hand.



**Milling Screw Machine Cam, Showing Use of Extension
for Spiral Head**

This shows the milling of a cam of long leads where the blank must be cut well up to the axis in one place. It is impossible to bring the spiral head spindle and the vertical attachment spindle near enough together to accomplish this deep cut when the spiral head is located in its usual position at the end of the table. The extension for the spiral head is designed to overcome this difficulty, and by using it the spiral head is located some distance in from the end of the table.

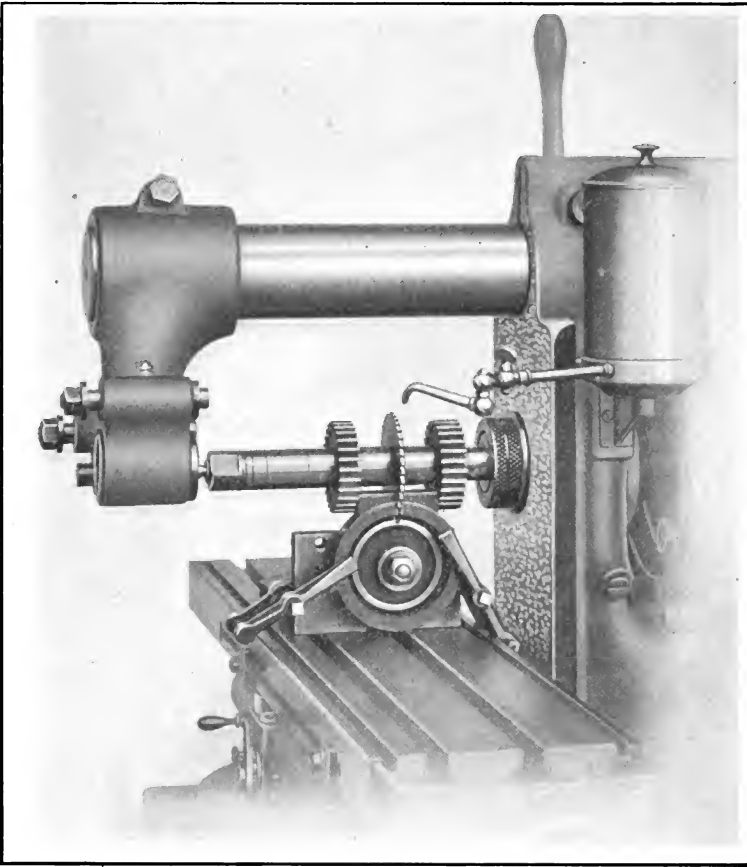
The cam in this case has three lobes, each having a different lead. Change gears to mill the longest lead are selected and then the angles of elevation of the head and attachment are changed to obtain the shorter leads while using the same change gears.



Milling Slot in Bushing, Using High Speed Milling Attachment

This operation furnishes a good illustration of the use of the high speed milling attachment. The end mill is only $\frac{3}{8}$ " in diameter, and where such small mills are used, it is necessary to run them at much higher speeds than are ordinarily obtainable on the machine, otherwise the finest feeds, either by power or hand, present material to the cutter faster than the teeth can remove it, and as a result, there is constant danger of breaking the mill. With the high speed attachment, the machine spindle speeds are multiplied so that suitable speeds to combine with the available feeds are obtainable.

The bushing being slotted is fastened in the vise at a proper height to bring the slot central.

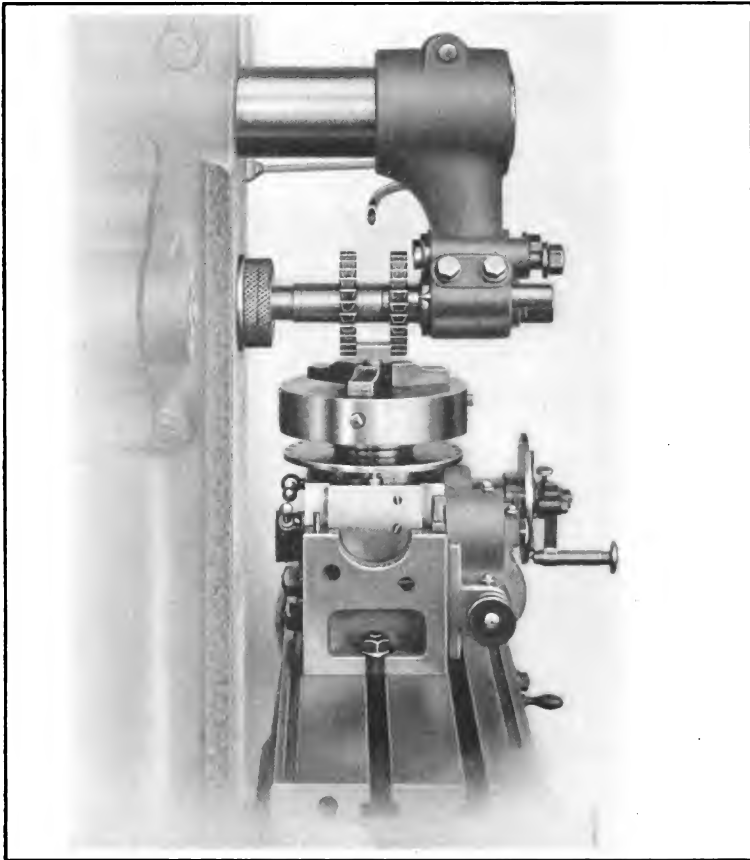


Milling Bearing Surfaces and Splitting Ring

This operation presents an example of light gang milling on work of an interesting character. The ring is required to have two flat bearing surfaces, one at each side of the projection on the top, and to be split midway between these bearings. All three operations are performed simultaneously by the method shown.

The ring is fastened to a knee by means of a nut and large washer in the centre, and clamps at each side prevent the piece from opening when cut through. When these pieces are milled in quantities a fixture is employed to hold them.

Two side milling cutters and a slitting saw comprise the gang.



Milling Bolt Heads

The illustration above shows a method of milling the heads of square and hexagonal bolts, using a chuck on the spiral head spindle for clamping the work. It also furnishes a good example of the use of a pair of side milling cutters as "straddle mills." Two sides are finished at a cut, therefore completing a square bolt head with two cuts and a hexagonal one with three cuts.

In indexing the work, the worm of the spiral head is thrown out of mesh and the divisions are obtained from the rapid index plate on the spindle nose.

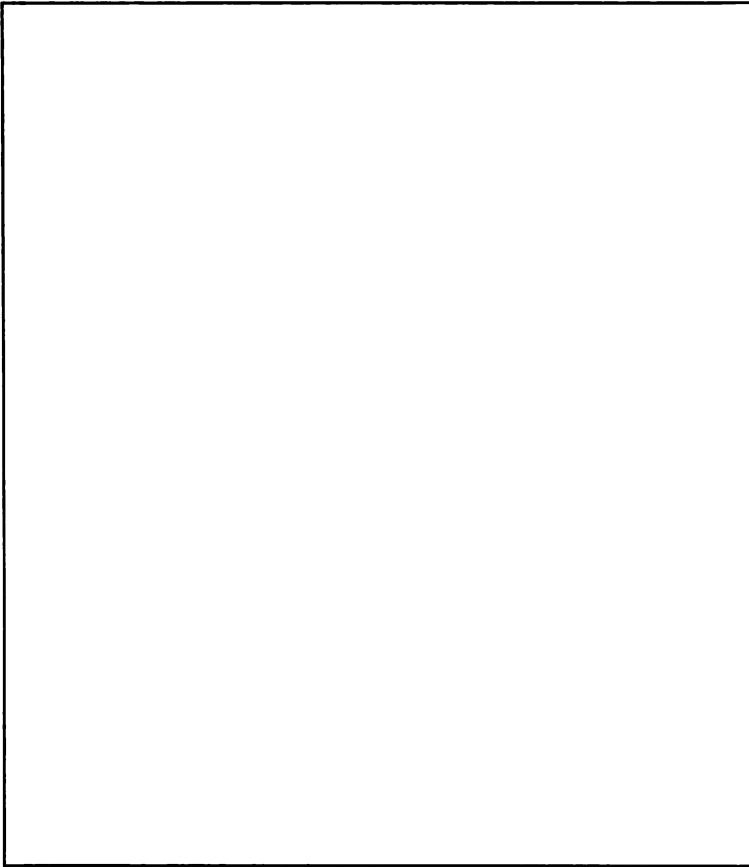
As the material is of wrought iron, oil is used in cutting.



Milling Angle on Block, Using Universal Milling Attachment

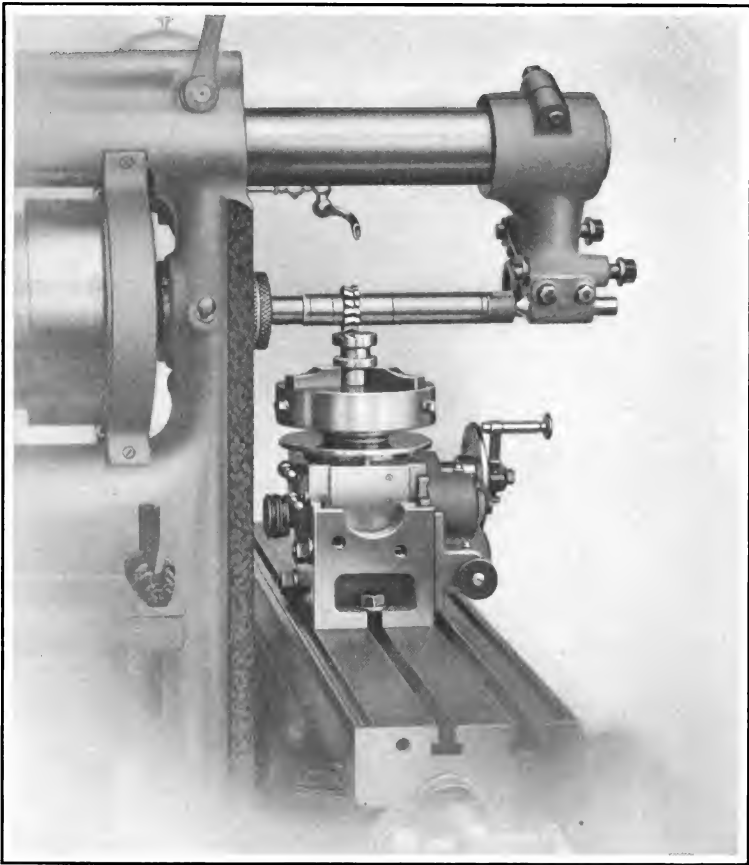
This operation is given chiefly to illustrate a use of the Universal Milling Attachment. This attachment may be set in a vertical, horizontal, or angular position without removing any part of it from the machine. Thus the opposite side of the piece of work shown can be milled without removing it from the vise. The table is simply moved to the left and the head of the attachment is swung to the required angle on the opposite side of the vertical.

In this manner both sides are milled so that they are exactly parallel to one another.



**Milling Angular Gib, Using Compound Vertical Spindle
Milling Attachment**

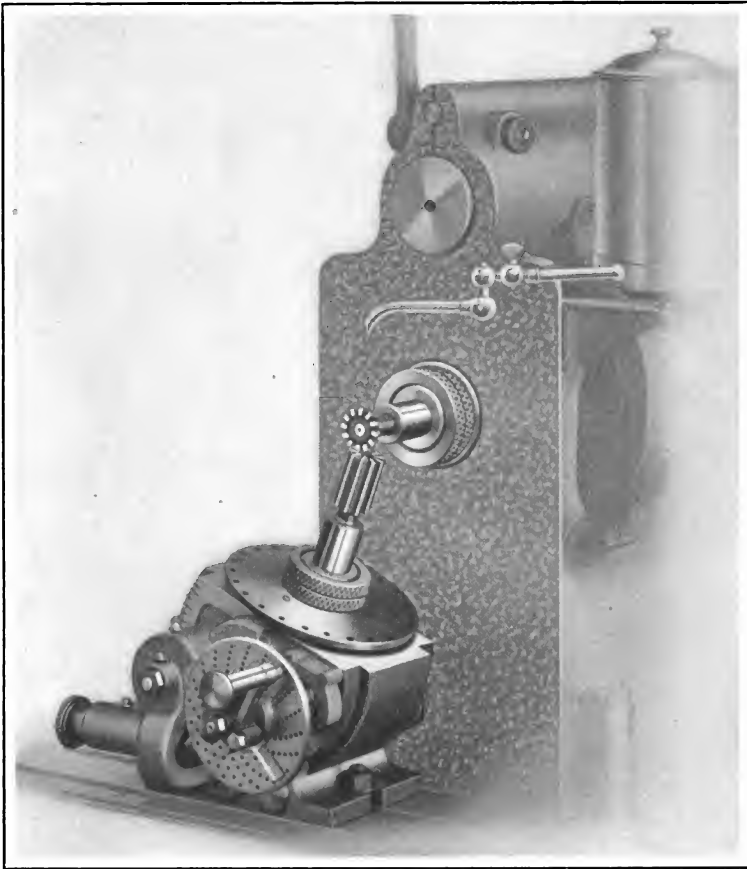
Angular cutters are not always at hand that will produce the proper angle on angular strips, gibs, etc., and when this is the case, the value of a Compound Vertical Spindle Milling Attachment can be appreciated. This attachment can be swung to mill a wide variety of different angles, using an ordinary end mill. It can be used to mill an angle on a long gib, similar to that shown above, or the head can be removed, turned quarter way around and put back in place, and used to mill an angle on a piece where, for some reason, it is advantageous to feed the table transversely.



Milling Clutch Teeth

This operation is very similar in the way it is set up to the one of Milling Bolts previously described. The character of the cut, however, is lighter and the arbor is supported at the outer end on a centre, whereas in the other operation, the end of the arbor runs in the arbor yoke bearing. A cutter of special form is used, and one tooth is finished at each cut, the cut beginning at the outside of blank and finishing in the centre.

Indexing in this case is accomplished with the regular index plates and crank as the number of teeth required cannot be indexed with the plate on the spindle nose.



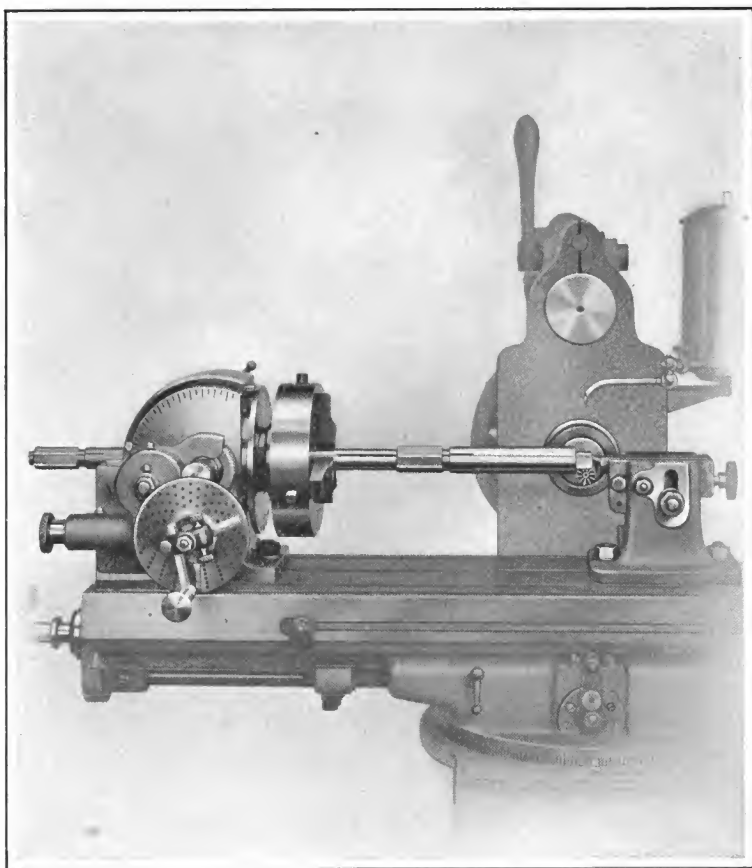
Milling End Teeth in End Mill

When it is required to mill end teeth in an end mill, it may be done as shown in the illustration above.

The mill is held by its shank in a collet that is inserted in the spiral head spindle. The spiral head is adjusted to an angle to give the correct form to the teeth.

An angular cutter is used and the table is fed longitudinally. Indexing is accomplished with the index plates and crank in the usual way.

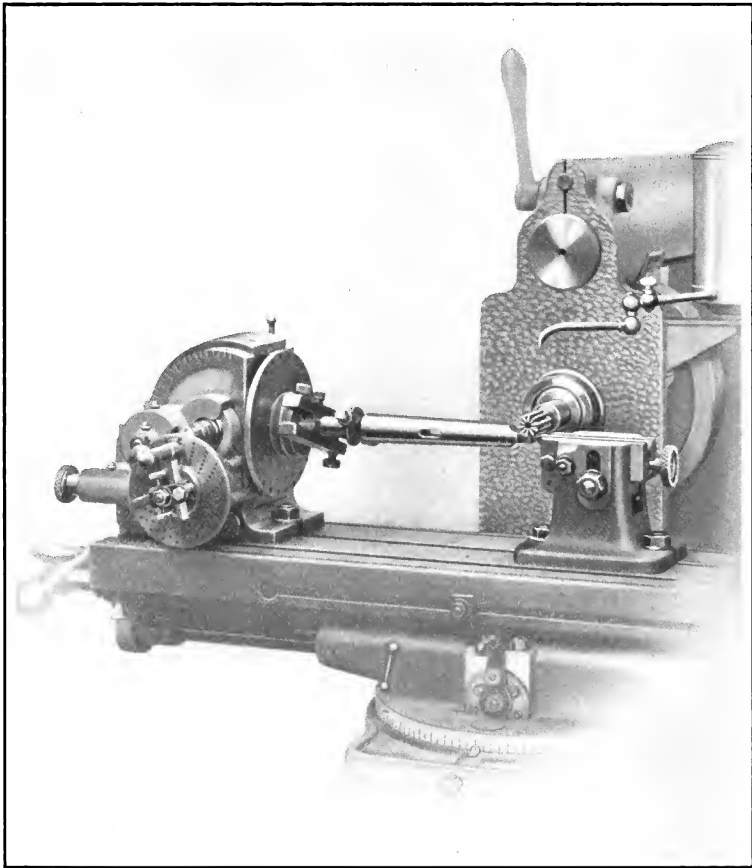
Oil is used, as the material of the end mill is tool steel.



Milling Squares for Wrench on Reamer Shank

A reamer of the type illustrated is necessarily rather long and cannot be accommodated on centres as a shorter piece would be. It is, therefore, passed through the hole in the spiral head spindle and is clamped in the chuck, while the wrench end is supported by the foot-stock centre.

An end mill is used and the work is fed vertically. To prevent longitudinal movement of table, the small clamping lever shown on the front of the saddle is set up. Where there are many pieces to be done, a more permanent method of fixing the table is by means of stops that fasten on to the V bearing at the bottom of the table and come against the side of the saddle.



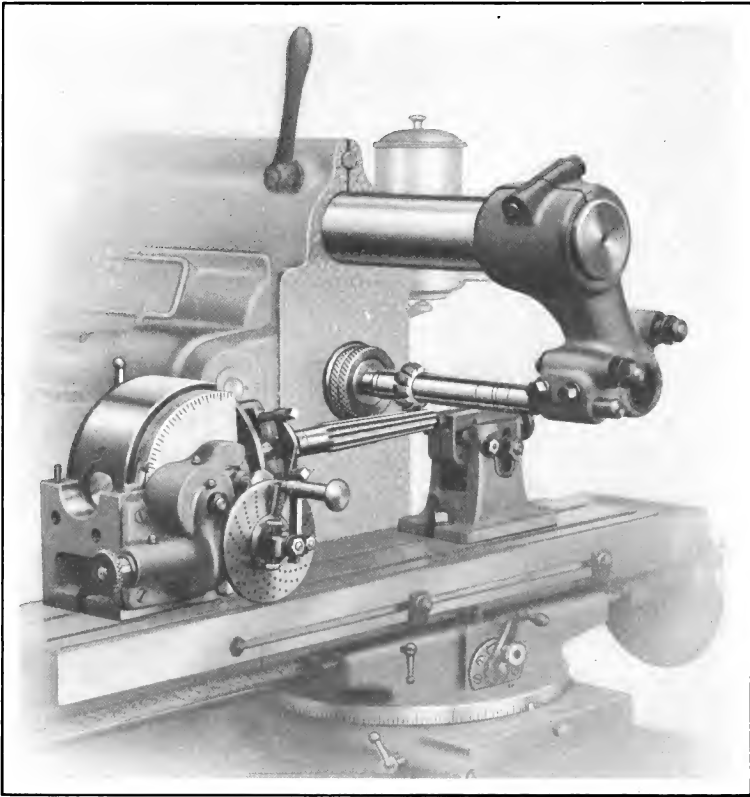
Milling Tenon on Collet

A taper plug having a centre hole at the large end is driven into the hole in the collet, which is then mounted on the spiral head centres. A dog on the taper plug locks the collet to the spiral head spindle.

An end mill is used and the cutting is done with the teeth on the periphery. The rapid index plate is used to index the work and the table is fed longitudinally.

The table feed trip dog is set to insure milling both sides to the same length.

If a quantity of this work is to be done, formed straddle mills would be employed with an entirely different arrangement.

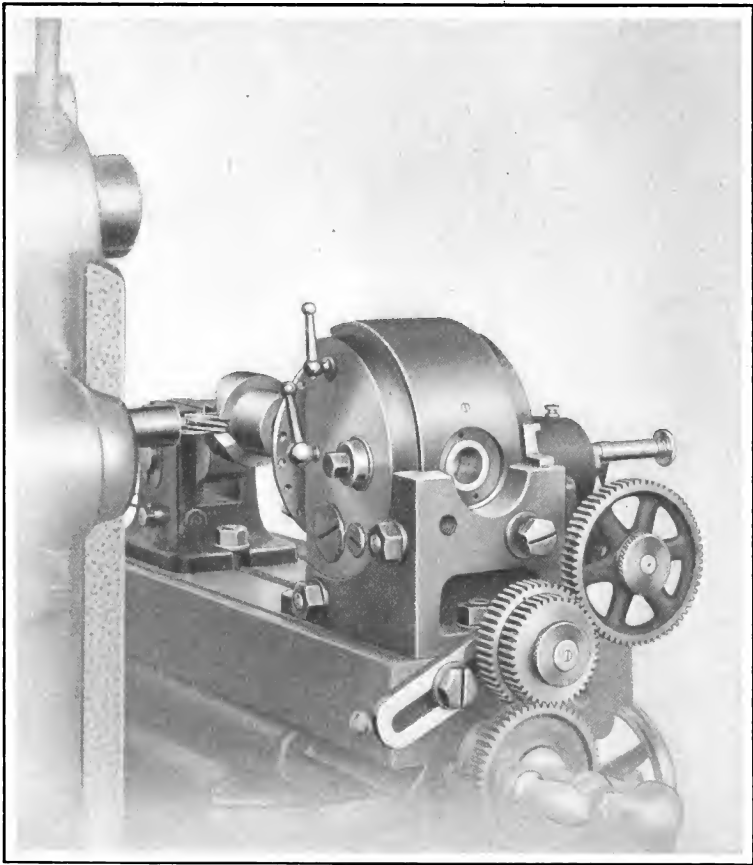


Milling Flutes in Taper Reamer

There are times when a shop requires a reamer of special size that cannot be procured readily, and in such cases one can be turned up and the flutes cut in the manner shown above. The spiral head is set at the angle of taper and the foot-stock centre is adjusted to correspond with it. The reamer blank is then mounted on the centres and dogged to the spiral head spindle.

A stock cutter, known as a reamer fluting cutter, is used and the table is fed longitudinally.

The procedure is the same for milling a straight reamer, except that the spiral head and foot-stock are set at zero.



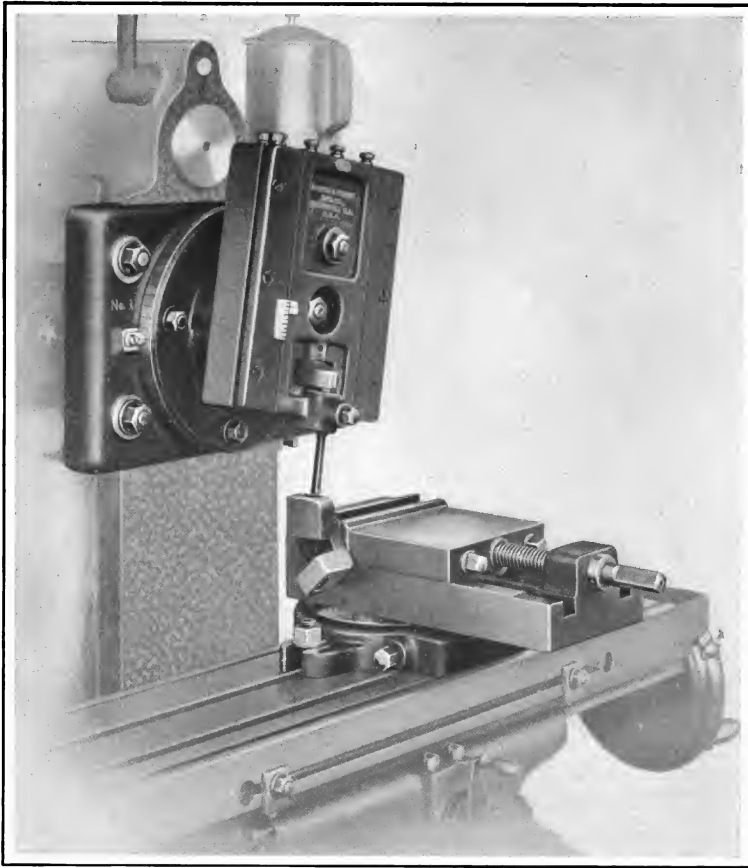
Cutting a Spiral with End Mill

When a spiral slot with parallel sides is required an end mill should be employed and the job set up as shown above.

The spiral head centres are brought to a level with the centre of the machine spindle.

The table is at right angles to the spindle and the angle of the spiral is obtained by the combination of change gears used.

Either right or left-hand spirals can be cut in this way by simply leaving out or interposing an intermediate gear in the train of change gears.

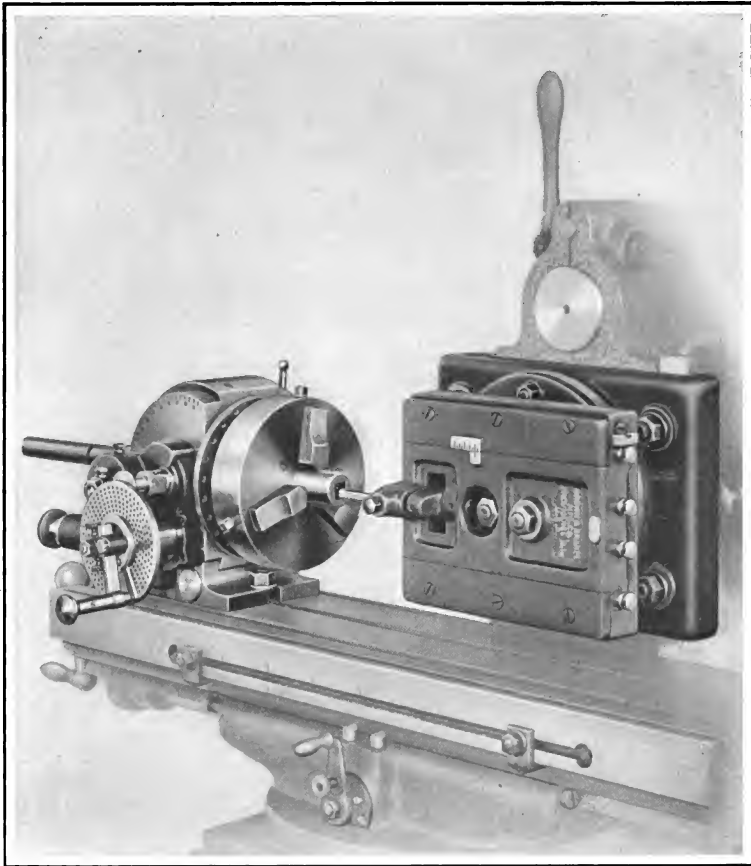


Cutting Slots in Screw Machine Tool, Using Slotting Attachment

The screw machine tool is held by its shank in a vise, and the slotting attachment is set at an angle so as to give the proper clearance to the cutter that is intended for use in the slot. A hole is drilled for starting the slot.

In slotting work, all necessary movements of the table are made by the hand feed.

The swivel vise is very useful in connection with the slotting attachment, for the work can be swung to any angle or indexed, if it is desired to make a special shaped slot.

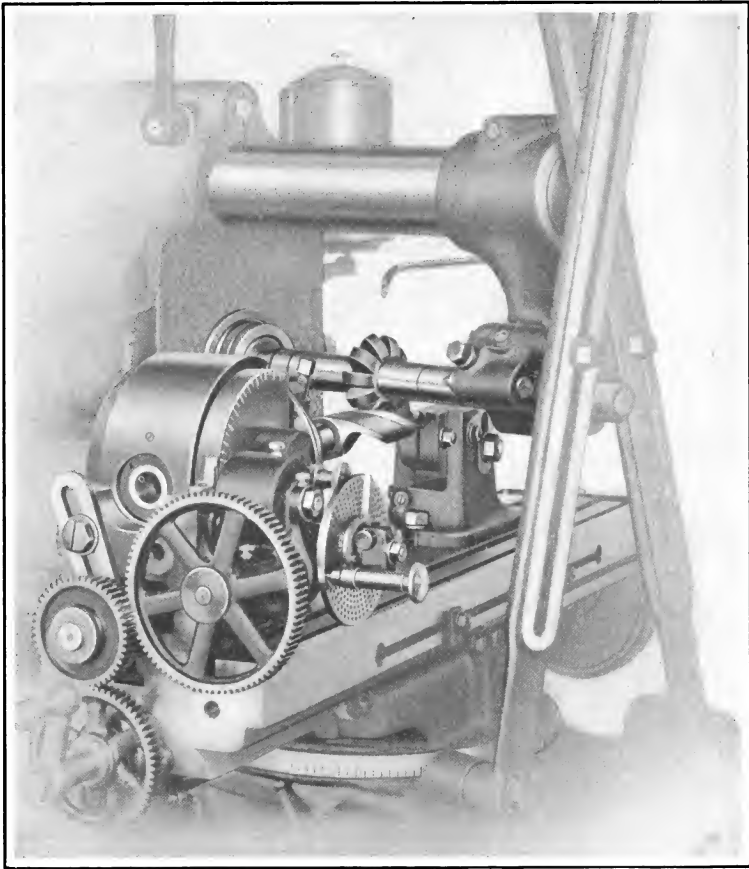


Slotting Square Hole in Extension Wrench

In this operation the piece of work is too long to be set in a vertical position; it is, therefore, passed through the spiral head spindle and is clamped in the chuck. The slotting attachment head is then set so that the tool moves in a path parallel to the top of the table.

The ability to swing the head from a vertical to a horizontal position is one of the features of the B. & S. attachment.

The piece of work is indexed by means of the rapid index plate. All necessary movements of the table are made by hand.

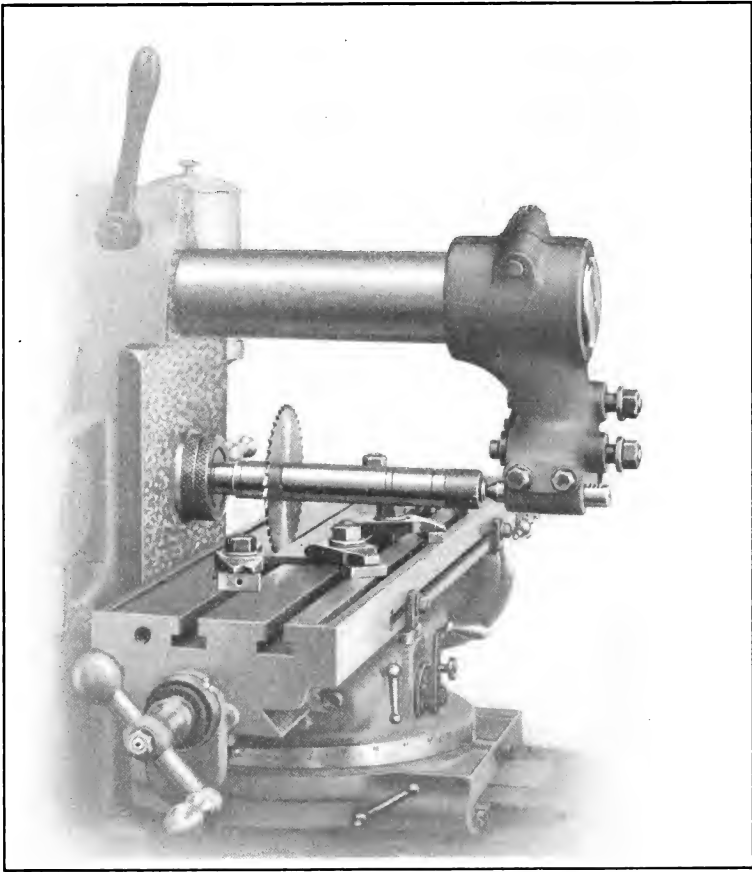


Milling Flutes of Twist Drill

This operation is very similar to that of cutting a spiral gear. The drill blank is mounted on the spiral head centres and fastened to the spindle with a dog. The spiral head is geared for the required lead and the necessary angle is obtained by swinging the swivel table.

As the character of the cut is heavy, the arm braces are employed to give additional rigidity to the arbor. A stock cutter of special form, known as a twist drill cutter, is employed and oil is used in cutting.

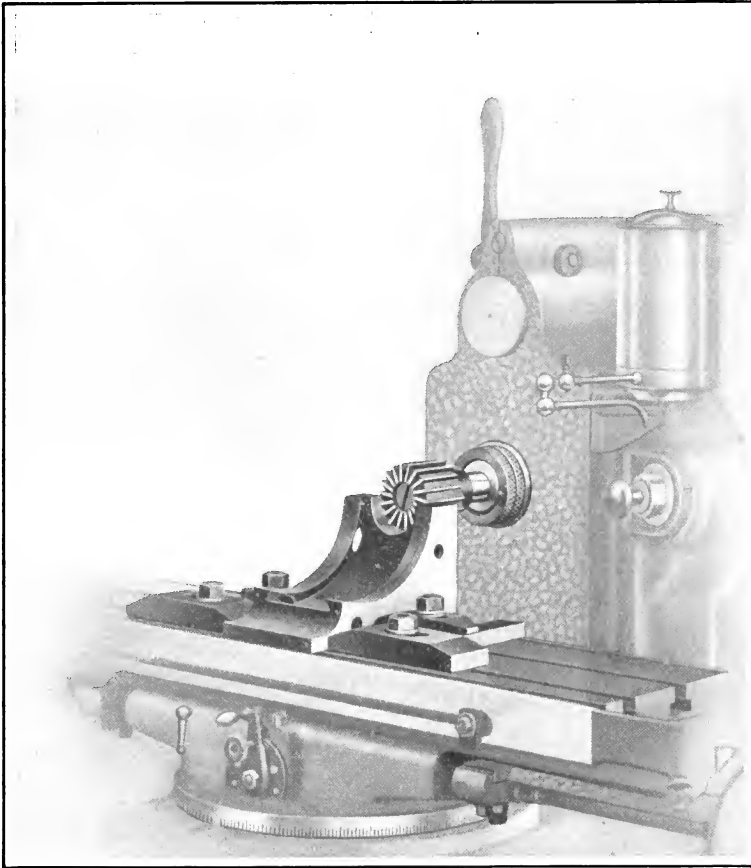
More complete information on this subject can be found in Chapter IV.



Sawing Flat Stock

When it is necessary to saw a piece of flat stock, it may be strapped directly to the table in a position so that the line where it is to be cut comes over a slot.

A metal slitting saw is used to split the piece and the table is fed in the same direction to that in which the saw revolves. This prevents the tendency to raise the work from the table and wedge the cutter; also for the cut to run out of a straight line. In feeding the table in this manner, every precaution should be taken to eliminate backlash from the feed screw.

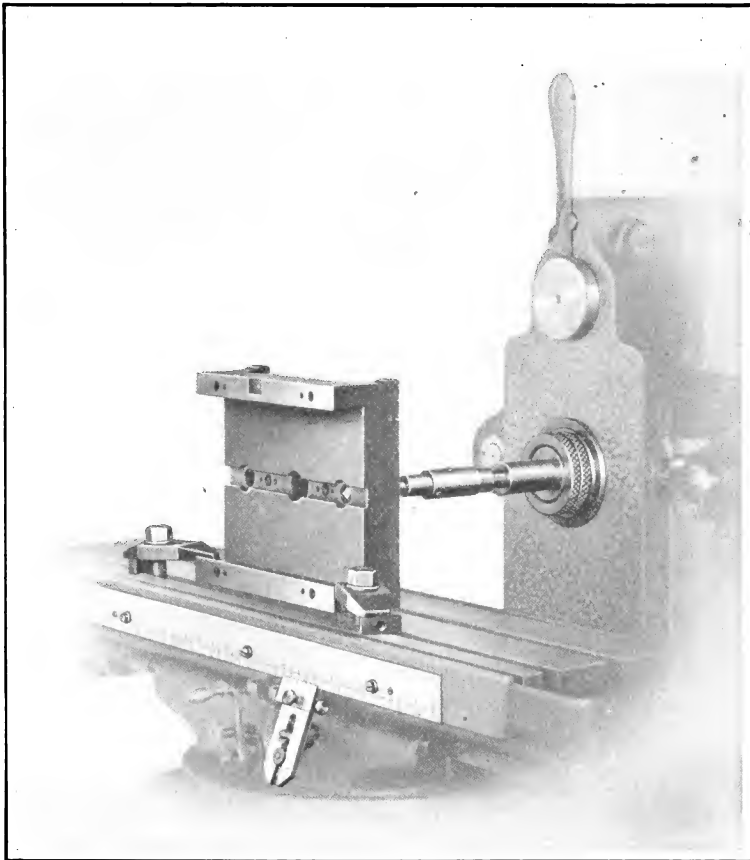


Milling Semi-Circle in Top of Spiral Head Base .

The casting is clamped directly to the table, as clearly shown in the illustration, and the knee is raised so that the top of the piece is in a line with the axis of the cutter.

A shell end mill is used and the table is fed transversely, bringing all the cutting upon the end teeth of the mill.

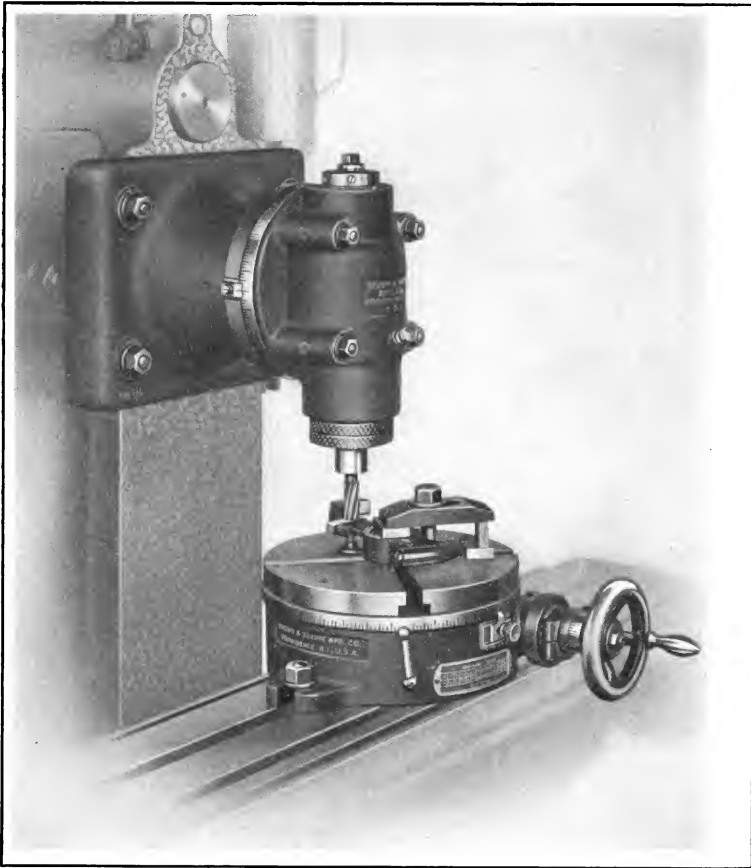
When a mill is used in this manner, it is well to grind the teeth on the periphery a little smaller at the back end, as this has a tendency to prevent chattering.



Boring Holes in Jig

The use of a scale and vernier in connection with a boring bar, boring holes where accurate spacing is required, is shown in this operation. Finer adjustments can be obtained in this way than are possible using the dial on the longitudinal hand feed screw.

The work is strapped to the table, and the boring bar, which is in reality a kind of fly tool, is held in a collet inserted in the spindle. Scales and verniers can also be furnished for the transverse and vertical movements of Brown & Sharpe milling machines.

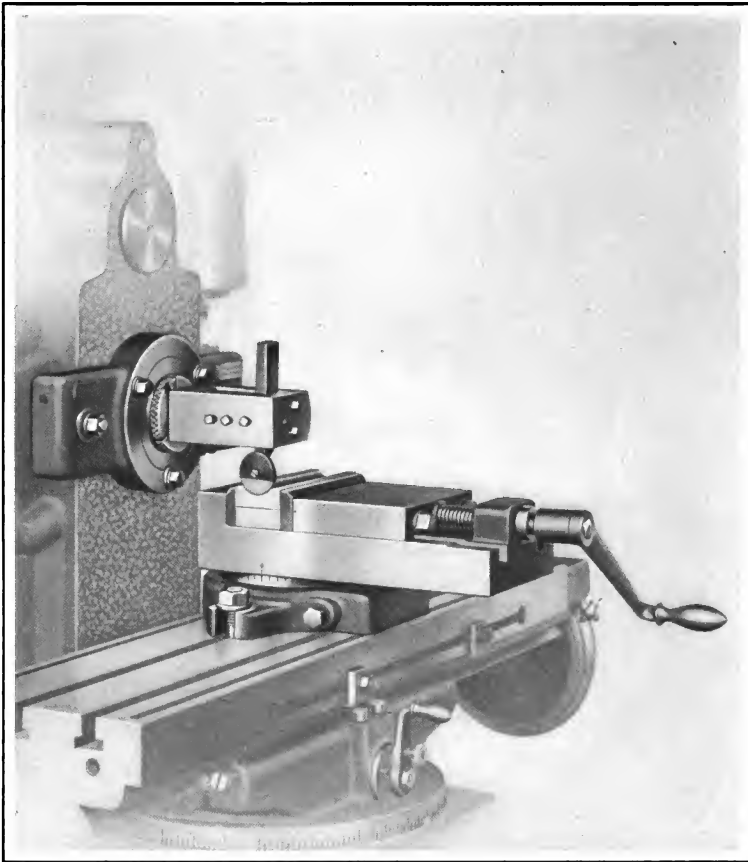


Milling Curved and Flat Surfaces at one Setting of Work, Using Vertical Spindle and Circular Milling Attachments

A combination of a vertical spindle and circular milling attachment is shown in this operation. With these two attachments, practically the same variety of work can be done as on a vertical spindle milling machine of equal capacity.

The job being done consists of milling a flat surface on the top of a piece and a curved surface at the end of it. The piece is set over a bushing inserted in the centre of the circular milling attachment table. The work is fed in a circular path by means of the hand-wheel, and when the flat cut is finished, the machine table is raised for milling the curved surface, but the work is not disturbed.

With a vertical spindle milling machine, only the circular milling attachment is needed.

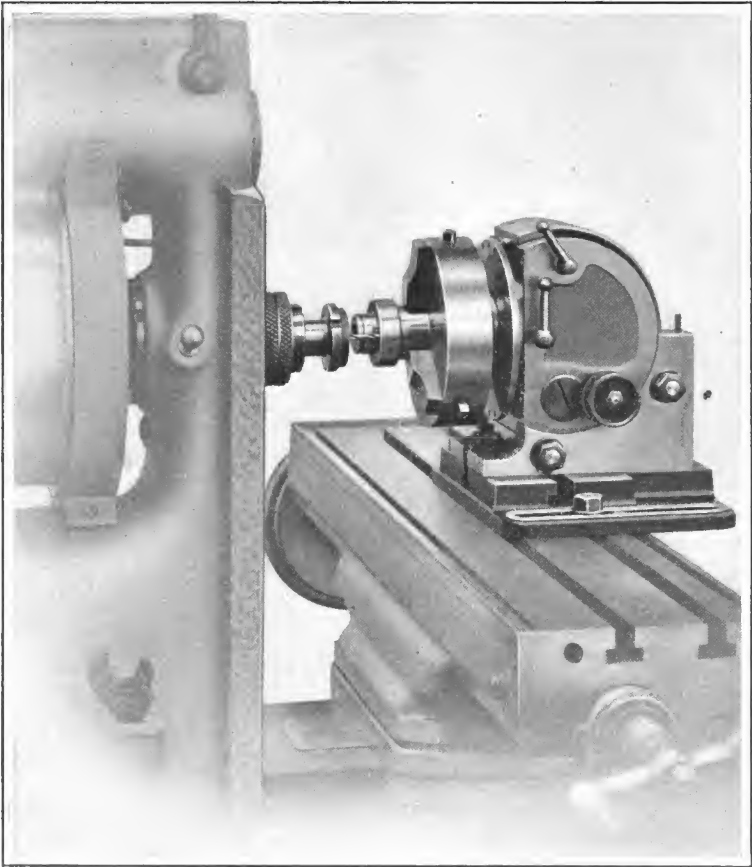


Planing on a Milling Machine

This illustration shows a comparatively unusual operation on the milling machine. Planing can be done on any milling machine by clamping the spindle and moving the table by hand; but on our constant speed drive machines, the spindle can be clamped and the power feeds for longitudinal movement of table are still available.

The special device for clamping the spindle consists of a split ring that fits on the nose of the spindle, over which a bracket is clamped to the column. A bevel sleeve contained in the bracket closes the split ring on the spindle when the three bolts are tightened.

A fly tool is used, and if power feed is utilized, the table is usually fed at its fastest feed. The work is fed upward or transversely by means of the vertical transverse or hand feeds—often both are employed.



Drilling Holes in Bushing

A method of drilling holes in round pieces of work where they are required to be exactly spaced is shown in this operation.

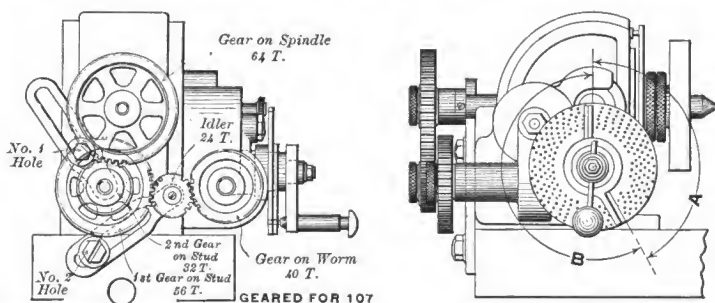
The bushing is held in the spiral head chuck and is indexed in the regular way, or with the rapid index plate, if the number of holes required can be obtained by the latter.

An ordinary twist drill, held in a spring chuck, is employed and the table is usually fed by hand. A collet can be employed for a drill having a taper shank.

TABLES

INDEX TABLE 2 to 50

PLAIN & DIFFERENTIAL INDEXING



NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION			
2	Any	20		13	39	3 $\frac{3}{39}$	14	26	39	1 $\frac{21}{39}$	106	40	Any	1				
3	39	13 $\frac{13}{39}$	65	14	49	2 $\frac{42}{49}$	169	27	27	1 $\frac{13}{27}$	95	41	41	$\frac{40}{41}$	3*			
	33	13 $\frac{11}{33}$	65		21	2 $\frac{18}{21}$	170	28	49	1 $\frac{21}{49}$	83	42	21	$\frac{20}{21}$	9*			
	18	13 $\frac{6}{18}$	65		39	2 $\frac{26}{39}$	132		21	1 $\frac{9}{21}$	85	43	43	$\frac{40}{43}$	12*			
4	Any	10		15	33	2 $\frac{22}{33}$	132	29	29	1 $\frac{11}{29}$	75	44	33	$\frac{30}{33}$	17*			
5	Any	8			18	2 $\frac{12}{18}$	132	30	39	1 $\frac{13}{39}$	65	45	27	$\frac{24}{27}$	21*			
6	39	6 $\frac{26}{39}$	132	16	20	2 $\frac{10}{20}$	98		33	1 $\frac{11}{33}$	65		18	$\frac{16}{18}$	21*			
	33	6 $\frac{22}{33}$	132	17	17	2 $\frac{6}{17}$	69		18	1 $\frac{6}{18}$	65	46	23	$\frac{20}{23}$	172			
7	18	6 $\frac{12}{18}$	132	18	27	2 $\frac{6}{27}$	43	31	31	1 $\frac{9}{31}$	56	47	47	$\frac{40}{47}$	168			
	49	5 $\frac{35}{49}$	140		18	2 $\frac{4}{18}$	43	32	20	1 $\frac{5}{20}$	48	48	18	$\frac{15}{18}$	165			
	21	5 $\frac{15}{21}$	142	19	19	2 $\frac{2}{19}$	19	33	33	1 $\frac{7}{33}$	41	49	49	$\frac{40}{49}$	161			
8	Any	5		20	Any	2		34	17	1 $\frac{3}{17}$	33	50	20	$\frac{16}{20}$	158			
9	27	4 $\frac{12}{27}$	88	21	21	1 $\frac{19}{21}$	18*	35	49	1 $\frac{7}{49}$	26	GRADUATIONS IN TABLE INDICATE SETTING FOR ARMS OF SECTOR WHEN INDEX CRANK MOVES THROUGH ARC "A," EXCEPT CASES MARKED * WHEN THE INDEX CRANK MOVES THROUGH ARC "B."						
	18	4 $\frac{8}{18}$	87	22	33	1 $\frac{27}{33}$	161		21	1 $\frac{3}{21}$	28							
10	Any	4		23	23	1 $\frac{17}{23}$	147	36	27	1 $\frac{3}{27}$	21							
11	33	3 $\frac{21}{33}$	126		39	1 $\frac{26}{39}$	132		18	1 $\frac{2}{18}$	21							
12	39	3 $\frac{13}{39}$	65	24	33	1 $\frac{22}{33}$	132	37	37	1 $\frac{3}{37}$	15				38	19	1 $\frac{1}{19}$	9
	33	3 $\frac{11}{33}$	65		18	1 $\frac{12}{18}$	132	39	39	1 $\frac{1}{39}$	3							
	18	3 $\frac{6}{18}$	65		25	20	1 $\frac{12}{20}$		118									

INDEX TABLE 51 to 92.

NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERs		NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERs	
					1st GEAR ON STUD	2nd GEAR ON STUD			No. 1 HOLE	No. 2 HOLE						1st GEAR ON STUD	2nd GEAR ON STUD			No. 1 HOLE	No. 2 HOLE
51	17	$\frac{14}{17}$	33*	24				48	24	44	69	20	$\frac{12}{20}$	118	40				56	24	44
52	39	$\frac{30}{39}$	152									49	$\frac{28}{49}$	112							
53	49	$\frac{35}{49}$	140	56	40	24	72				70	21	$\frac{12}{21}$	113							
	21	$\frac{15}{21}$	142	56	40	24	72					27	$\frac{15}{27}$	110	72			40	24		
54	27	$\frac{20}{27}$	147								71	18	$\frac{10}{18}$	109	72			40	24		
55	33	$\frac{24}{33}$	144									27	$\frac{15}{27}$	110							
56	49	$\frac{35}{49}$	140								72	18	$\frac{10}{18}$	109							
	21	$\frac{15}{21}$	142									49	$\frac{28}{49}$	112	28			48	24	44	
57	49	$\frac{35}{49}$	140	56			40	24	44		73	21	$\frac{12}{21}$	113	28			48	24	44	
	21	$\frac{15}{21}$	142	56			40	24	44			37	$\frac{20}{37}$	107							
58	29	$\frac{20}{29}$	136								75	15	$\frac{8}{15}$	105							
59	39	$\frac{26}{39}$	132	48			32	44			76	19	$\frac{10}{19}$	103							
	33	$\frac{22}{33}$	132	48			32	44			77	20	$\frac{10}{20}$	98	32			48	44		
	18	$\frac{12}{18}$	132	48			32	44			78	39	$\frac{20}{39}$	101							
60	39	$\frac{26}{39}$	132								79	20	$\frac{10}{20}$	98	48			24	44		
	33	$\frac{22}{33}$	132								80	20	$\frac{10}{20}$	98							
	18	$\frac{12}{18}$	132								81	20	$\frac{10}{20}$	98	48			24	24	44	
61	39	$\frac{26}{39}$	132	48			32	24	44		82	41	$\frac{20}{41}$	96							
	33	$\frac{22}{33}$	132	48			32	24	44		83	26	$\frac{10}{26}$	98	32			48	24	44	
	18	$\frac{12}{18}$	132	48			32	24	44		84	21	$\frac{10}{21}$	94							
62	31	$\frac{20}{31}$	127								85	17	$\frac{8}{17}$	92							
63	39	$\frac{26}{39}$	132	24			48	24	44		86	43	$\frac{20}{43}$	91							
	33	$\frac{22}{33}$	132	24			48	24	44		87	15	$\frac{7}{15}$	92	40			24	24	44	
	18	$\frac{12}{18}$	132	24			48	24	44		88	33	$\frac{15}{33}$	89							
64	16	$\frac{10}{16}$	123								89	27	$\frac{12}{27}$	88	72			32	44		
65	39	$\frac{24}{39}$	121									18	$\frac{8}{18}$	87	72			32	44		
66	33	$\frac{20}{33}$	120								90	27	$\frac{12}{27}$	88							
67	49	$\frac{28}{49}$	112	28			48	44				18	$\frac{8}{18}$	87							
	21	$\frac{12}{21}$	113	28			48	44			91	39	$\frac{18}{39}$	91	24			48	24	44	
68	17	$\frac{10}{17}$	116								92	23	$\frac{10}{23}$	86							

INDEX TABLE 93 to 125.

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE						1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
93	27	$\frac{12}{27}$	88	24			32	24	44	114	39	$\frac{13}{39}$	65	24			48	44	
	18	$\frac{8}{18}$	87	24			32	24	44		33	$\frac{11}{33}$	65	24			48	44	
94	47	$\frac{20}{47}$	83								18	$\frac{6}{18}$	65	24			48	44	
95	19	$\frac{8}{19}$	82							115	23	$\frac{8}{23}$	68						
96	49	$\frac{21}{49}$	83	28			32	24	44	116	29	$\frac{10}{29}$	68						
	21	$\frac{9}{21}$	85	28			32	24	44		39	$\frac{13}{39}$	65	24			24	56	
97	20	$\frac{8}{20}$	78	40			48	44		117	33	$\frac{11}{33}$	65	24			24	56	
98	49	$\frac{20}{49}$	79								18	$\frac{6}{18}$	65	24			24	56	
99	20	$\frac{8}{20}$	78	56	28	40	32			118	39	$\frac{13}{39}$	65	48			32	44	
100	20	$\frac{8}{20}$	78								33	$\frac{11}{33}$	65	48			32	44	
101	20	$\frac{8}{20}$	78	72	24	40	48		24	119	18	$\frac{6}{18}$	65	48			32	44	
102	20	$\frac{8}{20}$	78	40			32	24	44		39	$\frac{13}{39}$	65	72			24	44	
103	20	$\frac{8}{20}$	78	40			48	24	44	120	33	$\frac{11}{33}$	65	72			24	44	
104	39	$\frac{15}{39}$	75								18	$\frac{6}{18}$	65	72			24	44	
105	21	$\frac{8}{21}$	75							121	39	$\frac{13}{39}$	65						
106	43	$\frac{16}{43}$	73	86	24	24	48				33	$\frac{11}{33}$	65						
107	20	$\frac{8}{20}$	78	40	56	32	64		24	122	18	$\frac{6}{18}$	65						
108	27	$\frac{10}{27}$	73								39	$\frac{13}{39}$	65	72			24	24 44	
109	16	$\frac{6}{16}$	73	32			28	24	44	123	33	$\frac{11}{33}$	65	72			24	24 44	
110	33	$\frac{12}{33}$	71								18	$\frac{6}{18}$	65	72			24	24 44	
111	39	$\frac{13}{39}$	65	24			72	32		124	39	$\frac{13}{39}$	65	48			32	24 44	
	33	$\frac{11}{33}$	65	24			72	32			33	$\frac{11}{33}$	65	48			32	24 44	
112	18	$\frac{6}{18}$	65	24			72	32		125	18	$\frac{6}{18}$	65	48			32	24 44	
	39	$\frac{13}{39}$	65	24			64	44			39	$\frac{13}{39}$	65	24			24	24 44	
113	33	$\frac{11}{33}$	65	24			64	44		126	33	$\frac{11}{33}$	65	24			24	24 44	
	18	$\frac{6}{18}$	65	24			64	44			18	$\frac{6}{18}$	65	24			24	24 44	
114	39	$\frac{13}{39}$	65	24			56	44		127	39	$\frac{13}{39}$	65	24			40	24 44	
	33	$\frac{11}{33}$	65	24			56	44			33	$\frac{11}{33}$	65	24			40	24 44	
115	18	$\frac{6}{18}$	65	24			56	44		128	18	$\frac{6}{18}$	65	24			40	24 44	

INDEX TABLE 126 to 168.

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERs			NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERs		
					1st GEAR ON STUD	2nd GEAR ON STUD	3rd GEAR ON STUD		No. 1 HOLE	No. 2 HOLE	No. 3 HOLE						1st GEAR ON STUD	2nd GEAR ON STUD	3rd GEAR ON STUD		No. 1 HOLE	No. 2 HOLE	No. 3 HOLE
126	39	$\frac{13}{39}$	65	24				48	24	44		143	49	$\frac{14}{49}$	55	28				24	24	44	
	33	$\frac{11}{33}$	65	24				48	24	44			21	$\frac{6}{21}$	56	28				24	24	44	
	18	$\frac{6}{18}$	65	24				48	24	44			18	$\frac{5}{18}$	54								
127	39	$\frac{13}{39}$	65	24				56	24	44		145	29	$\frac{8}{29}$	54								
	33	$\frac{11}{33}$	65	24				56	24	44		146	49	$\frac{14}{49}$	55	28				48	24	44	
	18	$\frac{6}{18}$	65	24				56	24	44			21	$\frac{6}{21}$	56	28				48	24	44	
128	16	$\frac{5}{16}$	61									147	49	$\frac{14}{49}$	55	24				48	24	44	
	39	$\frac{13}{39}$	65	24				72	24	44			21	$\frac{6}{21}$	56	24				48	24	44	
	33	$\frac{11}{33}$	65	24				72	24	44		148	37	$\frac{10}{37}$	53								
129	18	$\frac{6}{18}$	65	24				72	24	44			49	$\frac{14}{49}$	55	28				72	24	44	
	39	$\frac{13}{39}$	60										21	$\frac{6}{21}$	56	28				72	24	44	
130	20	$\frac{6}{20}$	58	40				28	44			150	15	$\frac{4}{15}$	52								
131	33	$\frac{10}{33}$	59									151	20	$\frac{5}{20}$	48	32				72	44		
133	49	$\frac{14}{49}$	55	24				48	44			152	19	$\frac{5}{19}$	51								
	21	$\frac{6}{21}$	56	24				48	44				20	$\frac{5}{20}$	48	32				56	44		
	49	$\frac{14}{49}$	55	28				48	44			154	20	$\frac{5}{20}$	48	32				48	44		
134	21	$\frac{6}{21}$	56	28				48	44				31	$\frac{8}{31}$	50								
	27	$\frac{8}{27}$	58										39	$\frac{10}{39}$	50								
136	17	$\frac{5}{17}$	57									157	20	$\frac{5}{20}$	48	32				24	56		
	49	$\frac{14}{49}$	55	28				24	56				20	$\frac{5}{20}$	48	48				24	44		
	21	$\frac{6}{21}$	56	28				24	56			159	20	$\frac{5}{20}$	48	64	32	56	28				
138	49	$\frac{14}{49}$	55	56				32	44				20	$\frac{5}{20}$	48								
	21	$\frac{6}{21}$	56	56				32	44				20	$\frac{5}{20}$	48	64	32	56	28			24	
	49	$\frac{14}{49}$	55	56	32	48	24					162	20	$\frac{5}{20}$	48	48				24	24	44	
139	21	$\frac{6}{21}$	56	56	32	48	24						20	$\frac{5}{20}$	48	32				24	24	44	
	49	$\frac{14}{49}$	55									164	41	$\frac{10}{41}$	47								
	21	$\frac{6}{21}$	56										33	$\frac{8}{33}$	47								
140	18	$\frac{5}{18}$	54	48				40	44			166	20	$\frac{5}{20}$	48	32				48	24	44	
	49	$\frac{14}{49}$	55	56				32	24	44			20	$\frac{5}{20}$	48	32				56	24	44	
	21	$\frac{6}{21}$	56	56				32	24	44			21	$\frac{5}{21}$	47								

INDEX TABLE 169 to 214.

NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE						1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
169	20	$\frac{5}{20}$	48	32			72	24	44	187	27	$\frac{6}{27}$	43	72	48	24	56		24
170	17	$\frac{4}{17}$	45								18	$\frac{4}{18}$	43	72	48	24	56		24
171	21	$\frac{5}{21}$	47	56			40	24	44	188	47	$\frac{10}{47}$	40						
172	43	$\frac{10}{43}$	44								27	$\frac{6}{27}$	43	32			64	24	44
173	27	$\frac{6}{27}$	43	72	56	32	64			189	18	$\frac{4}{18}$	43	32			64	24	44
	18	$\frac{4}{18}$	43	72	56	32	64				19	$\frac{4}{19}$	40						
174	27	$\frac{6}{27}$	43	24			32	56		191	20	$\frac{4}{20}$	38	40			72	24	
	18	$\frac{4}{18}$	43	24			32	56			20	$\frac{4}{20}$	38	40			64	44	
175	27	$\frac{6}{27}$	43	72	40	32	64			193	20	$\frac{4}{20}$	38	40			56	44	
	18	$\frac{4}{18}$	43	72	40	32	64				20	$\frac{4}{20}$	38	40			48	44	
176	27	$\frac{6}{27}$	43	72	24	24	64			195	39	$\frac{8}{39}$	39						
	18	$\frac{4}{18}$	43	72	24	24	64				49	$\frac{10}{49}$	38						
177	27	$\frac{6}{27}$	43	72			48	24		197	20	$\frac{4}{20}$	38	40			24	56	
	18	$\frac{4}{18}$	43	72			48	24			20	$\frac{4}{20}$	38	56	28	40	32		
178	27	$\frac{6}{27}$	43	72			32	44		199	20	$\frac{4}{20}$	38	100	40	64	32		
	18	$\frac{4}{18}$	43	72			32	44			20	$\frac{4}{20}$	38						
179	27	$\frac{6}{27}$	43	72	24	48	32			201	20	$\frac{4}{20}$	38	72	24	40	24		24
	18	$\frac{4}{18}$	43	72	24	48	32				20	$\frac{4}{20}$	38	72	24	40	48		24
180	27	$\frac{6}{27}$	43							203	20	$\frac{4}{20}$	38	40			24	24	44
	18	$\frac{4}{18}$	43								20	$\frac{4}{20}$	38	40			32	24	44
181	27	$\frac{6}{27}$	43	72	24	48	32		24	205	41	$\frac{8}{41}$	37						
	18	$\frac{4}{18}$	43	72	24	48	32		24		20	$\frac{4}{20}$	38	40			48	24	44
182	27	$\frac{6}{27}$	43	72			32	24	44	207	20	$\frac{4}{20}$	38	40			56	24	44
	18	$\frac{4}{18}$	43	72			32	24	44		20	$\frac{4}{20}$	38	40			64	24	44
183	27	$\frac{6}{27}$	43	48			32	24	44	209	20	$\frac{4}{20}$	38	40			72	24	44
	18	$\frac{4}{18}$	43	48			32	24	44		21	$\frac{4}{21}$	37						
184	23	$\frac{5}{23}$	42							211	16	$\frac{3}{16}$	36	64			28	44	
185	37	$\frac{8}{37}$	42								43	$\frac{8}{43}$	35	86	24	24	48		
186	27	$\frac{6}{27}$	43	48			64	24	44	213	27	$\frac{5}{27}$	36	72			40	44	
	18	$\frac{4}{18}$	43	48			64	24	44		20	$\frac{4}{20}$	38	40	56	32	64		24

INDEX TABLE 215 to 270.

NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERS	
					1ST GEAR ON STUD	2ND GEAR ON STUD			No. 1 HOLE	No. 2 HOLE						1ST GEAR ON STUD	2ND GEAR ON STUD			No. 1 HOLE	No. 2 HOLE
215	43	$\frac{8}{43}$	35								245	49	$\frac{8}{49}$	30							
216	27	$\frac{5}{27}$	36								246	18	$\frac{3}{18}$	32	24			24	24	44	
217	21	$\frac{4}{21}$	37	48			64	24	44		247	18	$\frac{3}{18}$	32	48			56	24	44	
218	16	$\frac{3}{16}$	36	64			56	24	44		248	31	$\frac{5}{31}$	31							
219	21	$\frac{4}{21}$	37	28			48	24	44		249	18	$\frac{3}{18}$	32	32			48	24	44	
220	33	$\frac{6}{33}$	35								250	18	$\frac{3}{18}$	32	24			40	24	44	
221	17	$\frac{3}{17}$	33	24			24	56			251	18	$\frac{3}{18}$	32	48	44	32	64		24	
222	18	$\frac{3}{18}$	32	24			72	44			252	18	$\frac{3}{18}$	32	24			48	24	44	
223	43	$\frac{8}{43}$	35	86	48	24	64		24		253	33	$\frac{5}{33}$	29	24			40	56		
224	18	$\frac{3}{18}$	32	24			64	44			254	18	$\frac{3}{18}$	32	24			56	24	44	
225	27	$\frac{5}{27}$	36	24			40	24	44		255	18	$\frac{3}{18}$	32	48	40	24	72		24	
226	18	$\frac{3}{18}$	32	24			56	44			256	18	$\frac{3}{18}$	32	24			64	24	44	
227	49	$\frac{8}{49}$	30	56	64	28	72				257	49	$\frac{8}{49}$	30	56	48	28	64		24	
228	18	$\frac{3}{18}$	32	24			48	44			258	43	$\frac{7}{43}$	31	32			64	24	44	
229	18	$\frac{3}{18}$	32	24			44	48			259	49	$\frac{7}{49}$	26	24			72	44		
230	23	$\frac{4}{23}$	34								260	21	$\frac{3}{21}$	28	24			72	44		
231	18	$\frac{3}{18}$	32	32			48	44			261	39	$\frac{6}{39}$	29							
232	29	$\frac{5}{29}$	33								262	29	$\frac{4}{29}$	26	48	64	24	72			
233	18	$\frac{3}{18}$	32	48			56	44			263	20	$\frac{3}{20}$	28	40			28	44		
234	18	$\frac{3}{18}$	32	24			24	56			264	49	$\frac{8}{49}$	30	56	64	28	72		24	
235	47	$\frac{8}{47}$	32								265	33	$\frac{5}{33}$	29							
236	18	$\frac{3}{18}$	32	48			32	44			266	49	$\frac{7}{49}$	26	56	40	24	72			
237	18	$\frac{3}{18}$	32	48			24	44			267	21	$\frac{3}{21}$	28	56	40	24	72			
238	18	$\frac{3}{18}$	32	72			24	44			268	49	$\frac{7}{49}$	26	32			64	44		
239	18	$\frac{3}{18}$	32	72	24	64	32				269	21	$\frac{3}{21}$	28	32			64	44		
240	18	$\frac{3}{18}$	32								270	27	$\frac{4}{27}$	28				32	44		
241	18	$\frac{3}{18}$	32	72	24	64	32		24			49	$\frac{7}{49}$	26	28			48	44		
242	18	$\frac{3}{18}$	32	72			24	24	44			21	$\frac{3}{21}$	28	28			48	44		
243	18	$\frac{3}{18}$	32	64			32	24	44			20	$\frac{3}{20}$	28	64	32	40	28		24	
244	18	$\frac{3}{18}$	32	48			32	24	44			27	$\frac{4}{27}$	28							

INDEX TABLE 271 to 310

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	NO. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	NO. 1 HOLE		GEAR ON SPINDLE	IDLERS	
					1ST GEAR ON STUD	2ND GEAR ON STUD		NO. 1 HOLE	NO. 2 HOLE						1ST GEAR ON STUD	2ND GEAR ON STUD		NO. 1 HOLE	NO. 2 HOLE
271	49	$\frac{7}{49}$	26	56			72	24		287	49	$\frac{7}{49}$	26	24			24	24	44
	21	$\frac{3}{21}$	28	56			72	24			21	$\frac{3}{21}$	28	24			24	24	44
272	49	$\frac{7}{49}$	26	56			64	24		288	49	$\frac{7}{49}$	26	28			32	24	44
	21	$\frac{3}{21}$	28	56			64	24			21	$\frac{3}{21}$	28	28			32	24	44
273	49	$\frac{7}{49}$	26	24			24	56		289	49	$\frac{7}{49}$	26	56	24	24	72		24
	21	$\frac{3}{21}$	28	24			24	56			21	$\frac{3}{21}$	28	56	24	24	72		24
274	49	$\frac{7}{49}$	26	56			48	44		290	29	$\frac{4}{29}$	26						
	21	$\frac{3}{21}$	28	56			48	44			15	$\frac{2}{15}$	25	40			48	44	
275	49	$\frac{7}{49}$	26	56			40	44		292	49	$\frac{7}{49}$	26	28			48	24	44
	21	$\frac{3}{21}$	28	56			40	44			21	$\frac{3}{21}$	28	28			48	24	44
276	49	$\frac{7}{49}$	26	56			32	44		293	15	$\frac{2}{15}$	25	48	32	40	56		
	21	$\frac{3}{21}$	28	56			32	44			49	$\frac{7}{49}$	26	24			48	24	44
277	49	$\frac{7}{49}$	26	56			24	44		294	21	$\frac{3}{21}$	28	24			48	24	44
	21	$\frac{3}{21}$	28	56			24	44			15	$\frac{2}{15}$	25	48			32	44	
278	49	$\frac{7}{49}$	26	56	32	48	24			296	37	$\frac{5}{37}$	26						
	21	$\frac{3}{21}$	28	56	32	48	24				33	$\frac{4}{33}$	23	28	48	24	56		
279	27	$\frac{4}{27}$	28	24			32	24	44	298	49	$\frac{7}{49}$	26	28			72	24	44
280	49	$\frac{7}{49}$	26								21	$\frac{3}{21}$	28	28			72	24	44
	21	$\frac{3}{21}$	28							299	23	$\frac{3}{23}$	25	24			24	56	
281	49	$\frac{7}{49}$	26	72	24	56	24		24	300	15	$\frac{2}{15}$	25						
	21	$\frac{3}{21}$	28	72	24	56	24		24		43	$\frac{6}{43}$	26	24			48	24	44
282	43	$\frac{6}{43}$	26	86	24	24	56			302	16	$\frac{2}{16}$	24	32			72	24	
283	49	$\frac{7}{49}$	26	56			24	24	44	303	15	$\frac{2}{15}$	25	72	24	40	48		24
	21	$\frac{3}{21}$	28	56			24	24	44		16	$\frac{2}{16}$	24	24			48	44	
284	49	$\frac{7}{49}$	26	56			32	24	44	305	15	$\frac{2}{15}$	25	48			32	24	44
	21	$\frac{3}{21}$	28	56			32	24	44		15	$\frac{2}{15}$	25	40			32	24	44
285	49	$\frac{7}{49}$	26	56			40	24	44	307	15	$\frac{2}{15}$	25	72	48	40	56		24
	21	$\frac{3}{21}$	28	56			40	24	44		16	$\frac{2}{16}$	24	32			48	44	
286	49	$\frac{7}{49}$	26	56			48	24	44	309	15	$\frac{2}{15}$	25	40			48	24	44
	21	$\frac{3}{21}$	28	56			48	24	44		31	$\frac{4}{31}$	24						

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE			GEAR ON SPINDLE	IDLERS	
					1ST GEAR ON STUD	2ND GEAR ON STUD			No. 1 HOLE	No. 2 HOLE						1ST GEAR ON STUD	2ND GEAR ON STUD			No. 1 HOLE	No. 2 HOLE
311	16	$\frac{2}{16}$	24	64	24	24	72				339	27	$\frac{3}{27}$	21	24			56	44		
312	39	$\frac{5}{39}$	24									18	$\frac{2}{18}$	21	24			56	44		
313	16	$\frac{2}{16}$	24	32			28	56			340	17	$\frac{2}{17}$	22							
314	16	$\frac{2}{16}$	24	32			24	56			341	43	$\frac{5}{43}$	21	86	24	32	40			
315	16	$\frac{2}{16}$	24	64			40	24			342	27	$\frac{3}{27}$	21	32			64	44		
316	16	$\frac{2}{16}$	24	64			32	44				18	$\frac{2}{18}$	21	32			64	44		
317	16	$\frac{2}{16}$	24	64			24	44			343	15	$\frac{2}{15}$	25	40	64	24	86		24	
318	16	$\frac{2}{16}$	24	56	28	48	24				344	43	$\frac{5}{43}$	21							
319	29	$\frac{4}{29}$	26	48	64	24	72		24		345	27	$\frac{3}{27}$	21	24			40	56		
320	16	$\frac{2}{16}$	24									18	$\frac{2}{18}$	21	24			40	56		
321	16	$\frac{2}{16}$	24	72	24	64	24		24		346	27	$\frac{3}{27}$	21	72	56	32	64			
322	23	$\frac{3}{23}$	25	32			64	24	44			18	$\frac{2}{18}$	21	72	56	32	64			
323	16	$\frac{2}{16}$	24	64			24	24	44		347	43	$\frac{5}{43}$	21	86	24	32	40		24	
324	16	$\frac{2}{16}$	24	64			32	24	44		348	27	$\frac{3}{27}$	21	24			32	56		
325	16	$\frac{2}{16}$	24	64			40	24	44			18	$\frac{2}{18}$	21	24			32	56		
326	16	$\frac{2}{16}$	24	32			24	24	44		349	27	$\frac{3}{27}$	21	72	44	24	48			
327	16	$\frac{2}{16}$	24	32			28	24	44			18	$\frac{2}{18}$	21	72	44	24	48			
328	41	$\frac{5}{41}$	23								350	27	$\frac{3}{27}$	21	72	40	32	64			
329	16	$\frac{2}{16}$	24	64	24	24	72		24			18	$\frac{2}{18}$	21	72	40	32	64			
330	33	$\frac{4}{33}$	23								351	27	$\frac{3}{27}$	21	24			24	56		
331	16	$\frac{2}{16}$	24	64	44	24	48		24			18	$\frac{2}{18}$	21	24			24	56		
332	16	$\frac{2}{16}$	24	32			48	24	44		352	27	$\frac{3}{27}$	21	72	24	24	64			
333	27	$\frac{3}{27}$	21	24			72	44				18	$\frac{2}{18}$	21	72	24	24	64			
334	16	$\frac{2}{16}$	24	32			56	24	44		353	27	$\frac{3}{27}$	21	72	24	24	56			
335	33	$\frac{4}{33}$	23	72	48	44	40		24			18	$\frac{2}{18}$	21	72						

INDEX TABLE 356 to 399.

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GRADUATION	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE						1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
356	27	$\frac{3}{27}$	21	72			32	24		374	27	$\frac{3}{27}$	21	72	56	32	64		24
	18	$\frac{2}{18}$	21	72			32	24			18	$\frac{2}{18}$	21	72	56	32	64		24
357	27	$\frac{3}{27}$	21	72			24	44		375	27	$\frac{3}{27}$	21	24			40	24	44
	18	$\frac{2}{18}$	21	72			24	44			18	$\frac{2}{18}$	21	24			40	24	44
358	27	$\frac{3}{27}$	21	72	32	48	24			376	47	$\frac{5}{47}$	19						
	18	$\frac{2}{18}$	21	72	32	48	24			377	29	$\frac{3}{29}$	19	24			24	56	
359	43	$\frac{5}{43}$	21	86	48	32	100		24	378	27	$\frac{3}{27}$	21	32			64	24	44
	27	$\frac{3}{27}$	21								18	$\frac{2}{18}$	21	32			64	24	44
360	18	$\frac{2}{18}$	21							379	20	$\frac{2}{20}$	18	48	56	40	72		
	18	$\frac{2}{18}$	21							380	19	$\frac{2}{19}$	19						
361	19	$\frac{2}{19}$	19	32			64	44			27	$\frac{3}{27}$	21	24			56	24	44
	27	$\frac{3}{27}$	21	72	28	56	32		24	381	18	$\frac{2}{18}$	21	24			56	24	44
362	18	$\frac{2}{18}$	21	72	28	56	32		24		20	$\frac{2}{20}$	18	40			72	24	
363	27	$\frac{3}{27}$	21	72			24	24	44	383	20	$\frac{2}{20}$	18	40			68*		
	18	$\frac{2}{18}$	21	72			24	24	44	384	20	$\frac{2}{20}$	18	40			64	44	
364	27	$\frac{3}{27}$	21	72			32	24	44	385	20	$\frac{2}{20}$	18	32			48	44	
	18	$\frac{2}{18}$	21	72			32	24	44	386	20	$\frac{2}{20}$	18	40			56	44	
365	20	$\frac{2}{20}$	18	32	48	24	56				43	$\frac{4}{43}$	15	32	56	28	64		
	27	$\frac{3}{27}$	21	48			32	24	44	388	20	$\frac{2}{20}$	18	40			48	44	
366	18	$\frac{2}{18}$	21	48			32	24	44		20	$\frac{2}{20}$	18	40			44	56	
367	27	$\frac{3}{27}$	21	72	24	24	56		24	390	39	$\frac{4}{39}$	17						
	18	$\frac{2}{18}$	21	72	24	24	56		24	391	20	$\frac{2}{20}$	18	48	24	40	72		
368	27	$\frac{3}{27}$	21	72	24	24	64		24		49	$\frac{5}{49}$	16						
	18	$\frac{2}{18}$	21	72	24	24	64		24	393	20	$\frac{2}{20}$	18	40			28	44	
369	41	$\frac{4}{41}$	18	32	56	28	64				20	$\frac{2}{20}$	18	40			24	56	
	37	$\frac{4}{37}$	20							395	20	$\frac{2}{20}$	18	64			32	44	
370	21	$\frac{2}{21}$	18	32	56	24	64				20	$\frac{2}{20}$	18	56	28	40	32		
	27	$\frac{3}{27}$	21	48			64	24	44	397	20	$\frac{2}{20}$	18	64	24	40	32		
372	18	$\frac{2}{18}$	21	48			64	24	44		20	$\frac{2}{20}$	18	100	40	64	32		
373	20	$\frac{2}{20}$	18	40	48	32	72			399	21	$\frac{2}{21}$	18	32			64	44	

* SPECIAL GEAR.

INDEX TABLE

Plain and Differential Indexing for Divisions from 383 to 1008

Many of these divisions can be obtained by plain indexing and differential indexing, using the gears furnished with the machines. By the addition of eight special change gears all divisions from 383 to 1008 may be indexed.

The special change gears required have the following numbers of teeth: 46, 47, 52, 58, 68, 70, 76, 84.

INDEX TABLE 383 TO 488

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
				1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
383	20	$\frac{2}{20}$	40			68*	44		436	20	$\frac{2}{20}$	40	48	24	72		24
384	20	$\frac{2}{20}$	40			64	44		437	23	$\frac{32}{23}$	32			64	44	
385	20	$\frac{2}{20}$	32			48	44		438	21	$\frac{2}{21}$	28			48	24	44
386	20	$\frac{2}{20}$	40			56	44		439	43	$\frac{4}{43}$	86	24	24	72		24
387	43	$\frac{4}{43}$	32	56	28	64			440	33	$\frac{3}{33}$						
388	20	$\frac{2}{20}$	40			48	44		441	21	$\frac{2}{21}$	32			64	24	44
389	20	$\frac{2}{20}$	40			44	56		442	20	$\frac{2}{20}$	40	56	24	72		24
390	39	$\frac{3}{39}$							443	20	$\frac{2}{20}$	40	48	24	86		24
391	20	$\frac{2}{20}$	48	24	40	72			444	21	$\frac{2}{21}$	56	48	24	64		24
392	49	$\frac{4}{49}$							445	33	$\frac{3}{33}$	64	32	44	40		24
393	20	$\frac{2}{20}$	40			28	44		446	33	$\frac{3}{33}$	44			24	24	48
394	20	$\frac{2}{20}$	40			24	56		447	21	$\frac{2}{21}$	28			72	24	44
395	20	$\frac{2}{20}$	64			32	44		448	20	$\frac{2}{20}$	40	64	24	72		24
396	20	$\frac{2}{20}$	56	28	40	32			449	33	$\frac{3}{33}$	64	32	44	72		24
397	20	$\frac{2}{20}$	64	24	40	32			450	33	$\frac{3}{33}$	44			40	24	32
398	20	$\frac{2}{20}$	100	40	64	32			451	33	$\frac{3}{33}$	24			24	24	44
399	21	$\frac{2}{21}$	32			64	44		452	33	$\frac{3}{33}$	44			48	24	40
400	20	$\frac{2}{20}$							453	33	$\frac{3}{33}$	44			52*	24	40
401	21	$\frac{2}{21}$	56	32	24	76*			454	49	$\frac{4}{49}$	56	64	28	72		
402	21	$\frac{2}{21}$	28			43	44		455	49	$\frac{4}{49}$	28	40	32	64		
403	20	$\frac{2}{20}$	64	24	40	32		24	456	21	$\frac{2}{21}$	56	64	24	72		24
404	20	$\frac{2}{20}$	72	24	40	48		24	457	33	$\frac{3}{33}$	44			68*	24	40
405	20	$\frac{2}{20}$	64			32	24	44	458	33	$\frac{3}{33}$	44			72	24	24
406	20	$\frac{2}{20}$	40			24	24	44	459	27	$\frac{2}{27}$	24	48	24	72		
407	20	$\frac{2}{20}$	40			28	24	44	460	23	$\frac{2}{23}$						
408	20	$\frac{2}{20}$	40			32	24	44	461	33	$\frac{3}{33}$	44	28	24	72		24
409	20	$\frac{2}{20}$	40	24	32	48		24	462	33	$\frac{3}{33}$	32			64	24	44
410	41	$\frac{4}{41}$							463	21	$\frac{2}{21}$	56	64	24	86		24
411	21	$\frac{2}{21}$	28			24	56		464	33	$\frac{3}{33}$	44	48	28	56		24
412	20	$\frac{2}{20}$	40			48	24	44	465	33	$\frac{3}{33}$	44	24	24	100		24
413	21	$\frac{2}{21}$	48			32	44		466	49	$\frac{4}{49}$	56	48	28	64		
414	21	$\frac{2}{21}$	56			32	44		467	33	$\frac{3}{33}$	44	48	32	72		24
415	20	$\frac{2}{20}$	32			48	24	44	468	39	$\frac{3}{39}$	28	48	24	56		
416	20	$\frac{2}{20}$	40			64	24	44	469	49	$\frac{4}{49}$	28			48	44	
417	21	$\frac{2}{21}$	56	32	48	24			470	47	$\frac{4}{47}$						
418	20	$\frac{2}{20}$	40			72	24	44	471	49	$\frac{4}{49}$	56	32	28	76*		
419	33	$\frac{3}{33}$	44	28	24	72			472	49	$\frac{4}{49}$	56	32	28	72		
420	21	$\frac{2}{21}$							473	33	$\frac{3}{33}$	48	64	32	72		24
421	20	$\frac{2}{20}$	48	56	40	72		24	474	49	$\frac{4}{49}$	56	32	28	64		
422	20	$\frac{2}{20}$	40	44	32	64		24	475	49	$\frac{4}{49}$	56	40	28	48		
423	21	$\frac{2}{21}$	72	24	56	48		24	476	49	$\frac{4}{49}$	56			64	24	
424	43	$\frac{4}{43}$	86	24	24	43			477	27	$\frac{2}{27}$	24	48	24	56		
425	21	$\frac{2}{21}$	72	48	56	40		24	478	49	$\frac{4}{49}$	56	24	28	64		
426	21	$\frac{2}{21}$	56			32	24	44	479	49	$\frac{4}{49}$	56	32	28	44		
427	20	$\frac{2}{20}$	40	48	32	72		24	480	49	$\frac{4}{49}$	56	32	28	40		
428	20	$\frac{2}{20}$	40	56	32	64		24	481	37	$\frac{3}{37}$	24			24	56	
429	21	$\frac{2}{21}$	28			24	24	44	482	33	$\frac{3}{33}$	44	56	24	72		24
430	43	$\frac{4}{43}$							483	49	$\frac{4}{49}$	56			32	44	
431	21	$\frac{2}{21}$	72	44	28	48		24	484	49	$\frac{4}{49}$	56	24	28	32		
432	20	$\frac{2}{20}$	40	56	28	64		24	485	23	$\frac{2}{23}$	46*	24	24	100		24
433	20	$\frac{2}{20}$	40	44	24	72		24	486	27	$\frac{2}{27}$	32	56	28	64		
434	21	$\frac{2}{21}$	48			64	24	44	487	39	$\frac{3}{39}$	24	72	52*	44		
435	21	$\frac{2}{21}$	28			40	24	44	488	33	$\frac{3}{33}$	44	64	24	72		24

SPECIAL GEARS:

46, 47, 52, 58, 68, 70, 76, 84

*SPECIAL GEAR

INDEX TABLE 489 TO 594

NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
				1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
489	23	$\frac{2}{3}$	46*	58*	32	64		24	542	39	$\frac{2}{3}$	52*	44	32	64		24
490	49	$\frac{4}{9}$							543	27	$\frac{4}{9}$	72	24	48	32		24
491	33	$\frac{3}{3}$	44	68*	24	72		24	544	15	$\frac{3}{3}$	40	56	24	64		
492	41	$\frac{4}{1}$	28	48	24	56			545	15	$\frac{4}{1}$	32	44	24	64		
493	29	$\frac{2}{9}$	32	64	24	72			546	39	$\frac{2}{9}$	32			64	24	44
494	39	$\frac{3}{9}$	32			64	44		547	27	$\frac{3}{9}$	72	32	48	56		24
495	27	$\frac{2}{7}$	32	40	24	64			548	27	$\frac{2}{7}$	72	32	48	64		24
496	49	$\frac{4}{9}$	56	24	28	32		24	549	27	$\frac{4}{9}$	72			48	24	24
497	49	$\frac{4}{9}$	56			32	24	44	550	15	$\frac{4}{9}$	32	40	24	64		
498	27	$\frac{2}{7}$	48	56	24	64			551	29	$\frac{2}{7}$	32			64	44	
499	49	$\frac{4}{9}$	56	24	28	48		24	552	27	$\frac{4}{9}$	72	24	24	64		24
500	49	$\frac{4}{9}$	56	32	28	40		24	553	49	$\frac{4}{9}$	28	48	24	72		24
501	49	$\frac{4}{9}$	56	32	28	44		24	554	27	$\frac{4}{9}$	72	56	48	64		
502	49	$\frac{4}{9}$	56	32	28	48		24	555	15	$\frac{4}{9}$	24			72	44	
503	23	$\frac{2}{3}$	46*	64	32	86		24	556	15	$\frac{2}{3}$	24	44	40	64		
504	49	$\frac{4}{9}$	56			64	24	24	557	15	$\frac{4}{9}$	40	32	24	86		
505	49	$\frac{4}{9}$	56	40	28	48		24	558	27	$\frac{4}{9}$	48			64	24	44
506	49	$\frac{4}{9}$	56	32	28	64		24	559	39	$\frac{4}{9}$	24			72	24	44
507	39	$\frac{3}{9}$	24			24	56		560	43	$\frac{3}{9}$	86	40	32	64		
508	49	$\frac{4}{9}$	56	32	28	72		24	561	27	$\frac{4}{9}$	72	56	32	64		24
509	49	$\frac{4}{9}$	56	32	28	76*		24	562	27	$\frac{4}{9}$	72	44	24	64		24
510	49	$\frac{4}{9}$	56	40	28	64		24	563	29	$\frac{4}{9}$	58*			68*	44	
511	49	$\frac{4}{9}$	28			48	24	44	564	43	$\frac{4}{9}$	86	24	24	56		
512	49	$\frac{4}{9}$	56	44	28	64		24	565	15	$\frac{4}{9}$	24			56	44	
513	27	$\frac{2}{7}$	32			64	44		566	43	$\frac{2}{7}$	86	24	24	44		
514	49	$\frac{4}{9}$	56	48	28	64		24	567	15	$\frac{4}{9}$	32	44	40	64		
515	27	$\frac{2}{7}$	72	32	24	100			568	15	$\frac{2}{7}$	40	32	24	64		
516	43	$\frac{4}{3}$	32	56	28	64			569	29	$\frac{4}{3}$	58*			44	24	
517	49	$\frac{4}{9}$	56	48	28	72		24	570	15	$\frac{4}{9}$	32			64	44	
518	49	$\frac{4}{9}$	28			64	24	44	571	43	$\frac{4}{9}$	86	28	64	32		
519	27	$\frac{2}{7}$	72	56	32	64			572	15	$\frac{2}{7}$	40	28	24	64		
520	39	$\frac{3}{9}$							573	15	$\frac{3}{9}$	40			72	24	
521	27	$\frac{2}{7}$	72	76*	48	64			574	41	$\frac{2}{7}$	32			64	24	44
522	29	$\frac{2}{9}$	48	64	24	72			575	15	$\frac{2}{9}$	24			40	44	
523	27	$\frac{2}{7}$	72	68*	48	64			576	15	$\frac{2}{7}$	40			64	24	
524	27	$\frac{2}{7}$	72	32	24	64			577	43	$\frac{2}{7}$	86		64	44		24
525	27	$\frac{2}{7}$	72	40	32	64			578	15	$\frac{2}{7}$	48	44	40	64		
526	49	$\frac{4}{9}$	56	64	28	72		24	579	15	$\frac{4}{9}$	40			56	44	
527	31	$\frac{3}{1}$	32	64	24	72			580	29	$\frac{3}{1}$						
528	27	$\frac{2}{7}$	72	24	24	64			581	15	$\frac{2}{7}$	48	32	40	76*		
529	27	$\frac{2}{7}$	72	44	48	64			582	15	$\frac{2}{7}$	40			48	44	
530	15	$\frac{1}{5}$	24	56	32	64			583	27	$\frac{1}{5}$	72	64	24	86		24
531	27	$\frac{2}{7}$	72			48	24		584	15	$\frac{2}{7}$	48	32	40	64		
532	27	$\frac{2}{7}$	72	32	48	64			585	15	$\frac{2}{7}$	24			24	56	
533	27	$\frac{2}{7}$	72	32	48	56			586	15	$\frac{2}{7}$	72	48	40	56		
534	27	$\frac{2}{7}$	72			32	44		587	29	$\frac{2}{7}$	58*			28	24	44
535	27	$\frac{2}{7}$	72	32	48	40			588	15	$\frac{2}{7}$	40			32	44	
536	39	$\frac{3}{9}$	52*			64	24	44	589	15	$\frac{3}{9}$	72	44	40	48		
537	27	$\frac{2}{7}$	72	28	56	32			590	15	$\frac{2}{7}$	48			32	44	
538	29	$\frac{2}{9}$	58*	56	24	72			591	15	$\frac{2}{9}$	40			24	44	
539	49	$\frac{4}{9}$	28	48	24	56		24	592	16	$\frac{4}{9}$	24			72	44	
540	27	$\frac{2}{7}$							593	15	$\frac{2}{7}$	72	28	40	48		
541	39	$\frac{3}{9}$	52*	56	32	48		24	594	33	$\frac{3}{9}$	32	56	28	64		

SPECIAL GEARS:

46, 47, 52, 58, 68, 70, 76, 84

*SPECIAL GEAR

INDEX TABLE 595 TO 700

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
				1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
595	15	$\frac{1}{15}$	72			24	44		648	16	$\frac{1}{15}$	64			32	24	44
596	15	$\frac{1}{15}$	72	24	40	32			649	33	$\frac{1}{15}$	72			48	24	
597	33	$\frac{1}{33}$	44	56	24	72			650	16	$\frac{1}{15}$	64			40	24	44
598	16	$\frac{1}{16}$	64	56	24	72			651	16	$\frac{1}{15}$	64			44	24	24
599	43	$\frac{1}{43}$	86	44	24	84		24	652	16	$\frac{1}{15}$	32			24	24	44
600	15	$\frac{1}{15}$							653	33	$\frac{1}{15}$	72	28	44	48		
601	29	$\frac{1}{29}$	58*	56	48	72	24	24	654	16	$\frac{1}{15}$	64			56	24	44
602	43	$\frac{1}{43}$	32			64	24	44	655	16	$\frac{1}{15}$	64	40	32	48		24
603	15	$\frac{1}{15}$	72	24	40	24		24	656	16	$\frac{1}{15}$	24			24	24	44
604	16	$\frac{1}{16}$	32			72	24		657	18	$\frac{1}{15}$	32	48	24	56		
605	15	$\frac{1}{15}$	72			24	24	44	658	16	$\frac{1}{15}$	64	24	24	72		24
606	15	$\frac{1}{15}$	72	24	40	48		24	659	16	$\frac{1}{15}$	64	24	24	76*		24
607	15	$\frac{1}{15}$	72	28	40	48		24	660	33	$\frac{1}{15}$						
608	16	$\frac{1}{16}$	32			64	44		661	16	$\frac{1}{15}$	64	56	48	72		24
609	15	$\frac{1}{15}$	40			24	24	44	662	16	$\frac{1}{15}$	64	44	24	48		24
610	15	$\frac{1}{15}$	48			32	24	44	663	17	$\frac{1}{17}$	24			24	56	
611	15	$\frac{1}{15}$	72	44	40	48		24	664	16	$\frac{1}{15}$	32			48	24	44
612	15	$\frac{1}{15}$	40			32	24	44	665	49	$\frac{1}{49}$	56			40	24	44
613	16	$\frac{1}{16}$	64	48	32	72			666	18	$\frac{1}{15}$	24			72	44	
614	15	$\frac{1}{15}$	72	48	40	56		24	667	16	$\frac{1}{15}$	64	48	32	72		24
615	15	$\frac{1}{15}$	24			24	24	44	668	16	$\frac{1}{15}$	32			56	24	44
616	16	$\frac{1}{16}$	32			48	44		669	33	$\frac{1}{33}$	44			24	24	24
617	33	$\frac{1}{33}$	44	32	24	86			670	33	$\frac{1}{33}$	72	48	44	40		24
618	15	$\frac{1}{15}$	40			48	24	44	671	33	$\frac{1}{33}$	24			48	24	24
619	16	$\frac{1}{16}$	48	28	32	72			672	18	$\frac{1}{15}$	72			64	44	
620	31	$\frac{1}{31}$							673	16	$\frac{1}{15}$	48	44	32	72		24
621	15	$\frac{1}{15}$	40			56	24	44	674	33	$\frac{1}{33}$	72	56	44	48		24
622	16	$\frac{1}{16}$	64	24	24	72			675	33	$\frac{1}{33}$	44			40	24	24
623	16	$\frac{1}{16}$	64	24	24	68*			676	16	$\frac{1}{15}$	32			72	24	44
624	16	$\frac{1}{16}$	24			24	56		677	18	$\frac{1}{15}$	48	32	24	86		
625	15	$\frac{1}{15}$	24			40	24	44	678	18	$\frac{1}{15}$	24			56	44	
626	16	$\frac{1}{16}$	32			28	56		679	49	$\frac{1}{49}$	28			44	24	40
627	15	$\frac{1}{15}$	40			72	24	44	680	17	$\frac{1}{17}$						
628	16	$\frac{1}{16}$	32			24	56		681	33	$\frac{1}{33}$	44			56	24	24
629	16	$\frac{1}{16}$	64			44	24		682	33	$\frac{1}{33}$	48			64	24	24
630	16	$\frac{1}{16}$	64			40	24		683	16	$\frac{1}{15}$	32			86	24	44
631	16	$\frac{1}{16}$	64	28	56	72			684	18	$\frac{1}{15}$	32			64	44	
632	16	$\frac{1}{16}$	64			32	44		685	18	$\frac{1}{15}$	24	56	48	40		
633	16	$\frac{1}{16}$	64			28	44		686	15	$\frac{1}{15}$	40	64	24	86		24
634	16	$\frac{1}{16}$	64			24	44		687	18	$\frac{1}{15}$	24			44	48	
635	15	$\frac{1}{15}$	24			56	24	44	688	16	$\frac{1}{15}$	24			72	24	44
636	16	$\frac{1}{16}$	56	28	48	24			689	39	$\frac{1}{39}$	24	48	24	56		
637	49	$\frac{1}{49}$	24			24	56		690	18	$\frac{1}{15}$	24			40	56	
638	29	$\frac{1}{29}$	48	64	24	72		24	691	18	$\frac{1}{15}$	48	32	24	58*		
639	33	$\frac{1}{33}$	44	28	32	64			692	18	$\frac{1}{15}$	72	56	32	64		
640	16	$\frac{1}{16}$							693	18	$\frac{1}{15}$	32			48	44	
641	33	$\frac{1}{33}$	44	32	48	76*			694	17	$\frac{1}{17}$	68*			56	24	44
642	16	$\frac{1}{16}$	72	24	64	24		24	695	18	$\frac{1}{15}$	72	24	24	100		
643	16	$\frac{1}{16}$	64	28	56	24		24	696	18	$\frac{1}{15}$	24			32	56	
644	49	$\frac{1}{49}$	56			32	44		697	17	$\frac{1}{17}$	24			24	24	44
645	15	$\frac{1}{15}$	24			72	24	44	698	18	$\frac{1}{15}$	72	44	24	48		
646	16	$\frac{1}{16}$	64			24	24	44	699	18	$\frac{1}{15}$	48			56	44	
647	16	$\frac{1}{16}$	64			28	24	44	700	18	$\frac{1}{15}$	72	40	32	64		

SPECIAL GEARS:

46, 47, 52, 58, 68, 70, 76, 84

*SPECIAL GEAR

INDEX TABLE 701 TO 806

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLERS	
				1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
701	17	$\frac{1}{17}$	68*	48	32	56		24	754	21	$\frac{1}{21}$	28	32	24	86		
702	18	$\frac{1}{18}$	24			24	56		755	20	$\frac{1}{20}$	32			72	44	
703	19	$\frac{1}{19}$	24			72	44		756	18	$\frac{1}{18}$	32			64	24	44
704	18	$\frac{1}{18}$	72	24	24	64			757	20	$\frac{1}{20}$	40			86		44
705	18	$\frac{1}{18}$	48			40	44		758	20	$\frac{1}{20}$	48	56	40	72		
706	18	$\frac{1}{18}$	72			56	24		759	33	$\frac{1}{33}$	24	48	24	72		24
707	18	$\frac{1}{18}$	72			52*	24		760	19	$\frac{1}{19}$						
708	18	$\frac{1}{18}$	72			48	24		761	39	$\frac{1}{39}$	52*	32	48	76*		
709	18	$\frac{1}{18}$	72			44	24		762	18	$\frac{1}{18}$	24			56	24	44
710	18	$\frac{1}{18}$	72			40	24		763	21	$\frac{1}{21}$	24	44	24	48		
711	18	$\frac{1}{18}$	64			32	44		764	20	$\frac{1}{20}$	40			72	24	
712	18	$\frac{1}{18}$	72			32	24		765	18	$\frac{1}{18}$	48	40	24	72		24
713	18	$\frac{1}{18}$	72			28	44		766	20	$\frac{1}{20}$	40			68*		44
714	18	$\frac{1}{18}$	72			24	44		767	39	$\frac{1}{39}$	48			32	44	
715	18	$\frac{1}{18}$	72	32	64	40			768	20	$\frac{1}{20}$	40			64	44	
716	18	$\frac{1}{18}$	72	28	56	32			769	19	$\frac{1}{19}$	76*	32	64	72		24
717	18	$\frac{1}{18}$	72	24	64	32			770	20	$\frac{1}{20}$	32			48	44	
718	33	$\frac{1}{33}$	44	58*	24	64		24	771	20	$\frac{1}{20}$	40			58*	44	
719	17	$\frac{1}{17}$	68*	52*	24	72		24	772	20	$\frac{1}{20}$	40			56	44	
720	18	$\frac{1}{18}$							773	20	$\frac{1}{20}$	40	24	32	72		
721	21	$\frac{1}{21}$	24	64	32	68*			774	18	$\frac{1}{18}$	24			72	24	44
722	19	$\frac{1}{19}$	32			64	44		775	20	$\frac{1}{20}$	32			40	44	
723	18	$\frac{1}{18}$	72	24	64	32		24	776	20	$\frac{1}{20}$	40			48	44	
724	18	$\frac{1}{18}$	72	28	56	32		24	777	21	$\frac{1}{21}$	24			72	44	
725	18	$\frac{1}{18}$	72	24	48	40			778	20	$\frac{1}{20}$	40			44	56	
726	18	$\frac{1}{18}$	72			24	24	44	779	20	$\frac{1}{20}$	32	28	40	48		
727	18	$\frac{1}{18}$	72			28	24	44	780	39	$\frac{1}{39}$						
728	18	$\frac{1}{18}$	72			32	24	44	781	20	$\frac{1}{20}$	48	24	40	76*		
729	18	$\frac{1}{18}$	64			32	24	44	782	20	$\frac{1}{20}$	48	24	40	72		
730	20	$\frac{1}{20}$	32	48	24	56			783	20	$\frac{1}{20}$	48	24	40	68		
731	17	$\frac{1}{17}$	48	56	28	72		24	784	20	$\frac{1}{20}$	40			32	44	
732	18	$\frac{1}{18}$	48			32	24	44	785	20	$\frac{1}{20}$	32			24	56	
733	18	$\frac{1}{18}$	72			52	44	24	786	20	$\frac{1}{20}$	40			28	44	
734	18	$\frac{1}{18}$	72			56	24	24	787	20	$\frac{1}{20}$	48	24	40	52*		
735	18	$\frac{1}{18}$	48			40	24	44	788	20	$\frac{1}{20}$	40			24	56	
736	18	$\frac{1}{18}$	72	24	24	64		24	789	20	$\frac{1}{20}$	48	24	40	44		
737	33	$\frac{1}{33}$	24	56	32	64		24	790	20	$\frac{1}{20}$	48			24	44	
738	41	$\frac{1}{41}$	32	56	28	64			791	20	$\frac{1}{20}$	64	24	40	48		
739	18	$\frac{1}{18}$	72	24	24	76*		24	792	20	$\frac{1}{20}$	56	28	40	32		
740	37	$\frac{1}{37}$							793	39	$\frac{1}{39}$	48			32	24	44
741	18	$\frac{1}{18}$	48			56	24	44	794	20	$\frac{1}{20}$	64	24	40	40		
742	21	$\frac{1}{21}$	32	56	24	64			795	20	$\frac{1}{20}$	64	32	56	28		
743	20	$\frac{1}{20}$	40	48	32	76*			796	20	$\frac{1}{20}$	100	40	64	32		
744	18	$\frac{1}{18}$	48			64	24	44	797	20	$\frac{1}{20}$	100	24	64	40		
745	18	$\frac{1}{18}$	72	24	24	100		24	798	21	$\frac{1}{21}$	24			48	44	
746	20	$\frac{1}{20}$	40	48	32	72			799	39	$\frac{1}{39}$	52*	32	48	76*		24
747	18	$\frac{1}{18}$	32			48	24	44	800	20	$\frac{1}{20}$						
748	18	$\frac{1}{18}$	72	64	32	56			801	21	$\frac{1}{21}$	28			52*	44	
749	19	$\frac{1}{19}$	76*			44		24	802	21	$\frac{1}{21}$	56	32	24	76*		
750	18	$\frac{1}{18}$	72			40	24	44	803	20	$\frac{1}{20}$	100	24	64	40		24
751	19	$\frac{1}{19}$	76*	24	32	48			804	21	$\frac{1}{21}$	28			48	44	
752	18	$\frac{1}{18}$	72	48	24	64		24	805	20	$\frac{1}{20}$	64	32	56	28		24
753	18	$\frac{1}{18}$	48	44	32	64		24	806	20	$\frac{1}{20}$	64	24	40	32		24

SPECIAL GEARS:

46, 47, 52, 58, 68, 70, 76, 84

*SPECIAL GEAR

INDEX TABLE 807 TO 912

NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLER		NUMBER OF DIVISIONS	INDEX CIRCLE	NO. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE		GEAR ON SPINDLE	IDLER	
				1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE					1ST GEAR ON STUD	2ND GEAR ON STUD		No. 1 HOLE	No. 2 HOLE
807	20	$\frac{1}{20}$	64	32	40	28		24	860	43	$\frac{2}{43}$						
808	20	$\frac{1}{20}$	72	24	40	48		24	861	21	$\frac{1}{21}$	24			24	24	44
809	20	$\frac{1}{20}$	64	24	40	48		24	862	21	$\frac{1}{21}$	72	44	28	48		24
810	20	$\frac{1}{20}$	48			24	24	44	863	20	$\frac{1}{20}$	40	56	32	72		24
811	20	$\frac{1}{20}$	64	32	40	44		24	864	21	$\frac{1}{21}$	28			32	24	44
812	20	$\frac{1}{20}$	40			24	24	44	865	21	$\frac{1}{21}$	56	32	48	100		24
813	21	$\frac{1}{21}$	56	24	24	72			866	20	$\frac{1}{20}$	40	44	24	72		24
814	20	$\frac{1}{20}$	40			28	24	44	867	21	$\frac{1}{21}$	56	24	24	72		24
815	20	$\frac{1}{20}$	32			24	24	44	868	21	$\frac{1}{21}$	48			64	24	44
816	20	$\frac{1}{20}$	40			32	24	44	869	43	$\frac{2}{43}$	86	24	48	72		24
817	43	$\frac{2}{43}$	24			48	44		870	21	$\frac{1}{21}$	28			40	24	44
818	20	$\frac{1}{20}$	40	24	32	48		24	871	43	$\frac{2}{43}$	86	24	24	44		24
819	39	$\frac{2}{39}$	24			48	24	44	872	20	$\frac{1}{20}$	40	48	24	72		24
820	41	$\frac{2}{41}$							873	21	$\frac{1}{21}$	56	48	24	44		24
821	20	$\frac{1}{20}$	32	28	40	48		24	874	23	$\frac{2}{23}$	32			64	44	
822	21	$\frac{1}{21}$	28			24	56		875	43	$\frac{2}{43}$	86	40	48	72		24
823	39	$\frac{2}{39}$	52*	32	24	86		24	876	21	$\frac{1}{21}$	28			48	24	44
824	20	$\frac{1}{20}$	40			48	24	44	877	23	$\frac{2}{23}$	46*	24	24	86		
825	21	$\frac{1}{21}$	56			40	44		878	43	$\frac{2}{43}$	86	24	24	72		24
826	21	$\frac{1}{21}$	48			32	44		879	43	$\frac{2}{43}$	86	24	24	76*		24
827	20	$\frac{1}{20}$	40	24	32	72		24	880	43	$\frac{2}{43}$	32	64	86	40		24
828	21	$\frac{1}{21}$	56			32	44		881	43	$\frac{2}{43}$	86	48	32	56		24
829	21	$\frac{1}{21}$	72	24	28	44			882	21	$\frac{1}{21}$	24			48	24	44
830	20	$\frac{1}{20}$	32			48	24	44	883	21	$\frac{1}{21}$	48	32	28	86		24
831	21	$\frac{1}{21}$	56			24	44		884	20	$\frac{1}{20}$	40	56	24	72		24
832	20	$\frac{1}{20}$	40			64	24	44	885	43	$\frac{2}{43}$	86	24	24	100		24
833	20	$\frac{1}{20}$	40	44	32	48		24	886	20	$\frac{1}{20}$	40	48	24	86		24
834	21	$\frac{1}{21}$	56	32	48	24			887	43	$\frac{2}{43}$	86	48	32	72		24
835	20	$\frac{1}{20}$	32			56	24	44	888	21	$\frac{1}{21}$	56	48	24	64		24
836	20	$\frac{1}{20}$	40			72	24	44	889	21	$\frac{1}{21}$	24			56	24	44
837	21	$\frac{1}{21}$	72	24	56	24			890	43	$\frac{2}{43}$	86	40	24	72		24
838	43	$\frac{2}{43}$	86	44	24	48		†	891	23	$\frac{2}{23}$	46*			58*	44	
839	43	$\frac{2}{43}$	86	48	32	56			892	43	$\frac{2}{43}$	86	48	24	64		24
840	21	$\frac{1}{21}$							893	43	$\frac{2}{43}$	86	44	24	72		24
841	43	$\frac{2}{43}$	86	24	24	76*			894	21	$\frac{1}{21}$	28			72	24	44
842	20	$\frac{1}{20}$	48	56	40	72		24	895	43	$\frac{2}{43}$	86	56	40	100		24
843	21	$\frac{1}{21}$	72	24	56	24		24	896	20	$\frac{1}{20}$	40	64	24	72		24
844	20	$\frac{1}{20}$	40	44	32	64		24	897	23	$\frac{2}{23}$	24			24	56	
845	20	$\frac{1}{20}$	32			72	24	44	898	23	$\frac{2}{23}$	46*			44	56	
846	43	$\frac{2}{43}$	86	24	24	56			899	23	$\frac{2}{23}$	46*	28	32	48		
847	21	$\frac{1}{21}$	72			24	24	44	900	43	$\frac{2}{43}$	86	64	40	100		24
848	43	$\frac{2}{43}$	86	24	24	48			901	23	$\frac{1}{23}$	48	24	46*	76*		
849	21	$\frac{1}{21}$	56			24	24	44	902	43	$\frac{2}{43}$	86	56	24	72		24
850	21	$\frac{1}{21}$	72	48	56	40		24	903	43	$\frac{2}{43}$	24			48	24	44
851	21	$\frac{1}{21}$	72	24	28	44		24	904	47	$\frac{2}{47}$	47			72		24
852	21	$\frac{1}{21}$	56			32	24	44	905	43	$\frac{2}{43}$	86	72	40	100		24
853	43	$\frac{2}{43}$	86			28	24		906	47	$\frac{2}{47}$	47			68*		24
854	20	$\frac{1}{20}$	40	48	32	72		24	907	23	$\frac{1}{23}$	48	24	46*	52*		
855	21	$\frac{1}{21}$	56			40	24	44	908	49	$\frac{2}{49}$	56	64	28	72		
856	20	$\frac{1}{20}$	40	56	32	64		24	909	23	$\frac{2}{23}$	48	24	46*	44		
857	21	$\frac{1}{21}$	72	24	28	68*		24	910	49	$\frac{2}{49}$	28	40	32	64		
858	21	$\frac{1}{21}$	28			24	24	44	911	23	$\frac{1}{23}$	46*	48	64	24		
859	21	$\frac{1}{21}$	56	32	48	76*		24	912	21	$\frac{1}{21}$	56	64	24	72		24

SPECIAL GEARS:

46, 47, 52, 58, 68, 70, 76, 84

† BOLT FOR 1ST AND 2ND STUD GEARS IN No. 2 HOLE

* SPECIAL GEAR

INDEX TABLE 913 TO 1008

NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE			IDLERS		NUMBER OF DIVISIONS	INDEX CIRCLE	No. OF TURNS OF INDEX	GEAR ON WORM	No. 1 HOLE			IDLERS	
				1ST GEAR ON STUD	2ND GEAR ON STUD	GEAR ON SPINDLE	No. 1 HOLE	No. 2 HOLE					1ST GEAR ON STUD	2ND GEAR ON STUD	GEAR ON SPINDLE	No. 1 HOLE	No. 2 HOLE
913	23	$\frac{1}{2 \cdot 3}$	48	24	46*	28			966	49	$\frac{2}{3 \cdot 9}$	56			32	44	
914	23	$\frac{1}{2 \cdot 3}$	48	24	46*	24			967	23	$\frac{2}{3 \cdot 9}$	46*	47*	24	48		24
915	21	$\frac{1}{2 \cdot 1}$	56	48	24	100		24	968	49	$\frac{2}{3 \cdot 9}$	56	24	28	32		
916	21	$\frac{1}{2 \cdot 1}$	28	32	24	76*		24	969	21	$\frac{1}{2 \cdot 1}$	28	48	24	86		24
917	49	$\frac{1}{4 \cdot 9}$	28			72	44		970	23	$\frac{1}{2 \cdot 3}$	46*	24	24	100		24
918	21	$\frac{1}{2 \cdot 1}$	28	64	32	52*		24	971	23	$\frac{1}{2 \cdot 3}$	46*	48	32	68*		24
919	47	$\frac{1}{4 \cdot 7}$	64	48	47*	56			972	27	$\frac{1}{3 \cdot 7}$	32	56	28	64		
920	23	$\frac{1}{2 \cdot 3}$							973	49	$\frac{2}{3 \cdot 9}$	56	32	48	24		
921	21	$\frac{1}{2 \cdot 1}$	32	48	28	72		24	974	23	$\frac{1}{2 \cdot 3}$	46*	48	32	72		24
922	49	$\frac{1}{4 \cdot 9}$	56	58*	28	64			975	27	$\frac{1}{3 \cdot 7}$	24	40	24	56		
923	49	$\frac{1}{4 \cdot 9}$	56	48	28	76*			976	23	$\frac{1}{2 \cdot 3}$	46*	48	24	56		24
924	49	$\frac{1}{4 \cdot 9}$	28			64	44		977	23	$\frac{1}{2 \cdot 3}$	46*	48	32	76*		24
925	21	$\frac{1}{2 \cdot 1}$	28	40	24	68*		24	978	23	$\frac{1}{2 \cdot 3}$	46*	58*	32	64		24
926	21	$\frac{1}{2 \cdot 1}$	56	64	24	86		24	979	47	$\frac{1}{4 \cdot 7}$	47*	48	32	52*		24
927	23	$\frac{1}{2 \cdot 3}$	48	24	46*	28		24	980	49	$\frac{2}{3 \cdot 9}$						
928	21	$\frac{1}{2 \cdot 1}$	28	44	24	64		24	981	27	$\frac{1}{3 \cdot 7}$	24	44	24	48		
929	23	$\frac{1}{2 \cdot 3}$	32	24	46*	24		24	982	47	$\frac{1}{4 \cdot 7}$	47*	48	32	56		24
930	49	$\frac{1}{4 \cdot 9}$	56	32	28	100			983	23	$\frac{1}{2 \cdot 3}$	46*	56	32	72		24
931	49	$\frac{1}{4 \cdot 9}$	24			48	44		984	23	$\frac{1}{2 \cdot 3}$	46*	48	24	64		24
932	49	$\frac{1}{4 \cdot 9}$	56	48	28	64			985	23	$\frac{1}{2 \cdot 3}$	46*	52*	40	100		24
933	23	$\frac{1}{2 \cdot 3}$	48	24	46*	52*		24	986	29	$\frac{1}{3 \cdot 9}$	32	64	24	72		
934	23	$\frac{1}{2 \cdot 3}$	46*	24	24	28		24	987	49	$\frac{2}{3 \cdot 9}$	56	24	48	32		24
935	49	$\frac{1}{4 \cdot 9}$	56	40	28	72			988	23	$\frac{1}{2 \cdot 3}$	46*	48	24	68*		24
936	49	$\frac{1}{4 \cdot 9}$	56	44	28	64			989	49	$\frac{2}{3 \cdot 9}$	56	24	28	24		24
937	49	$\frac{1}{4 \cdot 9}$	56	32	28	86			990	27	$\frac{1}{3 \cdot 7}$	32	40	24	64		
938	49	$\frac{1}{4 \cdot 9}$	28			48	44		991	49	$\frac{2}{3 \cdot 9}$	70*	40	56	44		24
939	21	$\frac{1}{2 \cdot 1}$	28	44	24	72		24	992	49	$\frac{2}{3 \cdot 9}$	56	24	28	32		24
940	47	$\frac{1}{4 \cdot 7}$							993	49	$\frac{2}{3 \cdot 9}$	70*	40	56	52*		24
941	23	$\frac{1}{2 \cdot 3}$	46*	28	32	48		24	994	49	$\frac{2}{3 \cdot 9}$	56			32	24	44
942	49	$\frac{1}{4 \cdot 9}$	56	32	28	76*			995	49	$\frac{2}{3 \cdot 9}$	56	24	28	40		24
943	23	$\frac{1}{2 \cdot 3}$	24			24	24	48	996	27	$\frac{1}{3 \cdot 7}$	48	56	24	64		
944	49	$\frac{1}{4 \cdot 9}$	56	32	28	72			997	49	$\frac{2}{3 \cdot 9}$	70*	40	56	68*		24
945	49	$\frac{1}{4 \cdot 9}$	28			40	44		998	49	$\frac{2}{3 \cdot 9}$	56	24	28	48		24
946	49	$\frac{1}{4 \cdot 9}$	56	32	28	68*			999	27	$\frac{1}{3 \cdot 7}$	24			72	44	
947	49	$\frac{1}{4 \cdot 9}$	56	44	28	48			1000	49	$\frac{2}{3 \cdot 9}$	56	32	28	40		24
948	49	$\frac{1}{4 \cdot 9}$	56	32	28	64			1001	49	$\frac{2}{3 \cdot 9}$	28			24	24	44
949	23	$\frac{1}{2 \cdot 3}$	46*	24	24	58*		24	1002	49	$\frac{2}{3 \cdot 9}$	56	32	28	44		24
950	49	$\frac{1}{4 \cdot 9}$	56	40	28	48			1003	49	$\frac{2}{3 \cdot 9}$	56	32	28	46*		24
951	49	$\frac{1}{4 \cdot 9}$	56	32	28	58*			1004	49	$\frac{2}{3 \cdot 9}$	56	32	28	48		24
952	49	$\frac{1}{4 \cdot 9}$	56			64	24		1005	27	$\frac{1}{3 \cdot 7}$	72	48	24	100		
953	49	$\frac{1}{4 \cdot 9}$	56	24	28	72			1006	23	$\frac{1}{2 \cdot 3}$	46*	64	32	86		24
954	49	$\frac{1}{4 \cdot 9}$	56	32	28	52*			1007	49	$\frac{2}{3 \cdot 9}$	56	24	28	72		24
955	23	$\frac{1}{2 \cdot 3}$	46*	40	32	56		24	1008	49	$\frac{2}{3 \cdot 9}$	56			64	24	24
956	49	$\frac{1}{4 \cdot 9}$	56	24	28	64											
957	49	$\frac{1}{4 \cdot 9}$	56	32	28	46*											
958	49	$\frac{1}{4 \cdot 9}$	56	32	28	44											
959	49	$\frac{1}{4 \cdot 9}$	28			24	56										
960	49	$\frac{1}{4 \cdot 9}$	56	32	28	40											
961	47	$\frac{1}{4 \cdot 7}$	47*	24	32	56		24									
962	49	$\frac{1}{4 \cdot 9}$	56	24	28	48											
963	23	$\frac{1}{2 \cdot 3}$	46*	24	24	86		24									
964	23	$\frac{1}{2 \cdot 3}$	46*	44	24	48		24									
965	49	$\frac{1}{4 \cdot 9}$	56	24	28	40											

SPECIAL GEARS:

46, 47, 52, 58, 68, 70, 76, 84

*SPECIAL GEAR

TABLE OF APPROXIMATE ANGLES FOR CUTTING SPIRALS

		GEAR ON WORM		1ST GEAR ON STUD		2ND GEAR ON STUD		GEAR ON SCREW		LEAD IN INCHES TO ONE TURN		TANGENT OF ANGLE OF SPIRAL = $\frac{\text{CIRCUMFERENCE OF CUTTER, DRILL, OR MILL}}{\text{LEAD IN INCHES TO ONE TURN}}$																								NOS. OF TEETH IN GEARS FURNISHED WITH MACHINE	
												$T = \frac{C}{L} \quad L = \frac{C}{T}$																								24(2) 28 32 40 44 48 56 64 72 86 100	
												THE LEAD IN INCHES TO ONE TURN																								10 X GEAR ON WORM X 2ND GEAR ON STUD GEAR ON SCREW X 1ST GEAR ON STUD	
												DIAMETER OF CUTTER, DRILL, OR MILL																									

EXAMPLE ILLUSTRATING USE OF TABLE
 DIAMETER OF CUTTER, DRILL, OR MILL..... 1 1/4"
 LEAD IN INCHES TO ONE TURN..... 3.140
 REQUIRED ANGLE TO NEAREST QUARTER DEGREE
 TO SET SADDLE OF UNIVERSAL MILLING MACHINE..... 51 1/2°

TABLE OF APPROXIMATE ANGLES FOR CUTTING SPIRALS

[illegible]

TABLE OF LEADS

This table contains all the leads that can be obtained with any possible combination of the change gears furnished with Universal Milling Machines made by Brown & Sharpe Mfg. Co., even though some of the leads are not available for use on account of the gears interfering or not reaching. Combinations of gears that are too small in diameter to reach for right-hand spirals can generally be used for left-hand spirals, as the reverse gear is then required and will enable the gears to reach. For further information regarding the use of these tables, see Chapter IV.

The change gears that are furnished with the machines have the following numbers of teeth: 24 (2 gears), 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100.

TABLE OF LEADS, .670" TO 2.182"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
.670	24	86	24	100	1.527	24	44	28	100	1.886	24	56	44	100
.781	24	86	28	100	1.550	24	72	40	86	1.905	24	56	32	72
.800	24	72	24	100	1.556	28	72	40	100	1.919	24	64	44	86
.893	24	86	32	100	1.563	24	86	56	100	1.920	24	40	32	100
.900	24	64	24	100	1.563	28	86	48	100	1.925	28	64	44	100
.930	24	72	24	86	1.595	24	56	32	86	1.944	24	48	28	72
.933	24	72	28	100	1.600	24	48	32	100	1.944	28	64	32	72
1.029	24	56	24	100	1.600	28	56	32	100	1.954	24	40	28	86
1.042	28	86	32	100	1.600	24	72	48	100	1.956	32	72	44	100
1.047	24	64	24	86	1.607	24	56	24	64	1.990	28	72	44	86
1.050	24	64	28	100	1.628	24	48	28	86	1.993	24	56	40	86
1.067	24	72	32	100	1.628	28	64	32	86	2.000	24	40	24	72
1.085	24	72	28	86	1.637	32	86	44	100	2.000	24	48	40	100
1.116	24	86	40	100	1.650	24	64	44	100	2.000	28	56	40	100
1.196	24	56	24	86	1.667	24	56	28	72	2.000	32	64	40	100
1.200	24	48	24	100	1.667	24	48	24	72	2.009	24	86	72	100
1.200	24	56	28	100	1.667	24	64	32	72	2.030	24	44	32	86
1.200	24	64	32	100	1.674	24	40	24	86	2.035	28	64	40	86
1.221	24	64	28	86	1.680	24	40	28	100	2.036	28	44	32	100
1.228	24	86	44	100	1.706	24	72	44	86	2.045	24	44	24	64
1.240	24	72	32	86	1.711	28	72	44	100	2.047	40	86	44	100
1.244	28	72	32	100	1.714	24	56	40	100	2.057	24	28	24	100
1.250	24	64	24	72	1.744	24	64	40	86	2.057	24	56	48	100
1.302	28	86	40	100	1.745	24	44	32	100	2.067	32	72	40	86
1.309	24	44	24	100	1.750	28	64	40	100	2.083	24	64	40	72
1.333	24	72	40	100	1.776	24	44	28	86	2.084	28	86	64	100
1.340	24	86	48	100	1.778	32	72	40	100	2.084	32	86	56	100
1.371	24	56	32	100	1.786	24	86	64	100	2.093	24	64	48	86
1.395	24	48	24	86	1.786	32	86	48	100	2.093	24	32	24	86
1.395	24	56	28	86	1.800	24	64	48	100	2.100	24	64	56	100
1.395	24	64	32	86	1.800	24	32	24	100	2.100	28	64	48	100
1.400	24	48	28	100	1.809	28	72	40	86	2.100	24	32	28	100
1.400	28	64	32	100	1.818	24	44	24	72	2.121	24	44	28	72
1.429	24	56	24	72	1.823	28	86	56	100	2.133	24	72	64	100
1.433	28	86	44	100	1.860	28	56	32	86	2.133	32	72	48	100
1.440	24	40	24	100	1.861	24	72	48	86	2.143	24	56	32	64
1.447	28	72	32	86	1.861	24	48	32	86	2.143	24	48	24	56
1.458	24	64	28	72	1.867	28	48	32	100	2.171	24	72	56	86
1.467	24	72	44	100	1.867	24	72	56	100	2.171	28	48	32	86
1.488	32	86	40	100	1.867	28	72	48	100	2.171	28	72	48	86
1.500	24	64	40	100	1.875	24	48	24	64	2.178	28	72	56	100
1.522	24	44	24	86	1.875	24	56	28	64	2.182	24	44	40	100

TABLE OF LEADS, 2.188" TO 3.080"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
2.188	24	48	28	64	2.500	24	48	28	56	2.800	24	24	28	100
2.193	24	56	44	86	2.500	28	56	32	64	2.800	32	64	56	100
2.200	24	48	44	100	2.500	24	64	48	72	2.800	24	48	56	100
2.200	28	56	44	100	2.500	24	48	32	64	2.812	24	32	24	64
2.200	32	64	44	100	2.500	24	32	24	72	2.828	28	44	32	72
2.222	24	48	32	72	2.514	32	56	44	100	2.843	40	72	44	86
2.222	28	56	32	72	2.532	28	72	56	86	2.845	32	72	64	100
2.233	40	86	48	100	2.537	24	44	40	86	2.849	28	64	56	86
2.233	24	40	32	86	2.546	28	44	40	100	2.857	24	48	32	56
2.238	28	64	44	86	2.558	32	64	44	86	2.857	24	56	48	72
2.240	28	40	32	100	2.558	28	56	44	86	2.857	24	28	24	72
2.250	24	40	24	64	2.558	24	48	44	86	2.865	44	86	56	100
2.274	32	72	44	86	2.567	28	48	44	100	2.867	86	72	24	100
2.286	32	56	40	100	2.571	24	40	24	56	2.880	24	40	48	100
2.292	24	64	44	72	2.593	28	48	32	72	2.894	28	72	64	86
2.326	32	64	40	86	2.605	28	40	32	86	2.894	32	72	56	86
2.326	24	48	40	86	2.605	40	86	56	100	2.909	32	44	40	100
2.326	28	56	40	86	2.618	24	44	48	100	2.917	24	64	56	72
2.333	28	48	40	100	2.619	24	56	44	72	2.917	28	64	48	72
2.333	24	40	28	72	2.625	24	40	28	64	2.917	28	48	32	64
2.338	24	44	24	56	2.640	24	40	44	100	2.917	24	32	28	72
2.344	28	86	72	100	2.658	32	56	40	86	2.924	32	56	44	86
2.368	28	44	32	86	2.667	40	72	48	100	2.933	44	72	48	100
2.381	32	86	64	100	2.667	32	48	40	100	2.934	32	48	44	100
2.381	24	56	40	72	2.667	24	40	32	72	2.946	24	56	44	64
2.386	24	44	28	64	2.674	28	64	44	72	2.950	28	44	40	86
2.392	24	56	48	86	2.678	24	56	40	64	2.977	40	86	64	100
2.392	24	28	24	86	2.679	32	86	72	100	2.984	28	48	44	86
2.400	28	56	48	100	2.700	24	64	72	100	3.000	24	40	28	56
2.400	32	64	48	100	2.713	28	48	40	86	3.000	24	40	32	64
2.424	24	44	32	72	2.727	24	44	32	64	3.000	24	32	40	100
2.431	28	64	40	72	2.727	24	44	28	56	3.000	40	64	48	100
2.442	24	32	28	86	2.727	24	44	24	48	3.000	24	40	24	48
2.442	28	64	48	86	2.743	24	56	64	100	3.030	24	44	40	72
2.442	24	64	56	86	2.743	32	56	48	100	3.044	24	44	48	86
2.445	40	72	44	100	2.743	24	28	32	100	3.055	28	44	48	100
2.450	28	64	56	100	2.750	40	64	44	100	3.055	24	44	56	100
2.456	44	86	48	100	2.778	32	64	40	72	3.056	32	64	44	72
2.481	32	72	48	86	2.778	24	48	40	72	3.056	28	56	44	72
2.481	24	72	64	86	2.778	40	56	28	72	3.056	24	48	44	72
2.489	32	72	56	100	2.791	28	56	48	86	3.070	24	40	44	86
2.489	28	72	64	100	2.791	32	64	48	86	3.080	28	40	44	100

TABLE OF LEADS, 3.086" TO 3.896"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
3.086	24	56	72	100	3.349	48	40	24	86	3.637	48	44	24	72
3.101	40	72	48	86	3.360	56	40	24	100	3.646	40	48	28	64
3.101	32	48	40	86	3.360	48	40	28	100	3.655	40	56	44	86
3.111	28	40	32	72	3.383	32	44	40	86	3.657	64	56	32	100
3.111	40	72	56	100	3.403	28	64	56	72	3.663	72	64	28	86
3.117	24	44	32	56	3.409	24	44	40	64	3.667	40	48	44	100
3.125	28	56	40	64	3.411	32	48	44	86	3.667	44	40	24	72
3.125	24	48	40	64	3.411	44	72	48	86	3.673	24	28	24	56
3.126	48	86	56	100	3.422	44	72	56	100	3.684	44	86	72	100
3.140	24	86	72	64	3.428	24	40	32	56	3.686	86	56	24	100
3.143	40	56	44	100	3.429	40	28	24	100	3.704	32	48	40	72
3.150	28	100	72	64	3.429	40	56	48	100	3.721	24	24	32	86
3.175	32	56	40	72	3.438	24	48	44	64	3.721	64	48	24	86
3.182	28	44	32	64	3.438	28	56	44	64	3.721	64	56	28	86
3.182	24	44	28	48	3.488	40	64	48	86	3.733	48	72	56	100
3.189	32	56	48	86	3.488	40	32	24	86	3.733	56	48	32	100
3.189	24	28	32	86	3.491	64	44	24	100	3.733	64	48	28	100
3.190	24	86	64	56	3.491	48	44	32	100	3.733	28	24	32	100
3.198	40	64	44	86	3.492	32	56	44	72	3.750	24	32	24	48
3.200	28	100	64	56	3.500	40	64	56	100	3.750	24	32	28	56
3.200	24	100	64	48	3.500	28	32	40	100	3.750	28	56	48	64
3.200	24	24	32	100	3.500	28	40	32	64	3.763	86	64	28	100
3.214	24	56	48	64	3.500	24	40	28	48	3.771	44	56	48	100
3.214	24	32	24	56	3.520	32	40	44	100	3.772	24	28	44	100
3.214	24	28	24	64	3.535	28	44	40	72	3.799	56	48	28	86
3.225	24	100	86	64	3.552	56	44	24	86	3.809	24	28	32	72
3.241	28	48	40	72	3.552	48	44	28	86	3.810	64	56	24	72
3.256	24	24	28	86	3.556	40	72	64	100	3.810	32	56	48	72
3.256	24	86	56	48	3.564	56	44	28	100	3.818	24	40	28	44
3.256	32	64	56	86	3.565	28	48	44	72	3.819	40	64	44	72
3.267	28	48	56	100	3.571	24	48	40	56	3.822	86	72	32	100
3.273	24	40	24	44	3.571	32	56	40	64	3.837	24	32	44	86
3.275	44	86	64	100	3.572	48	86	64	100	3.837	44	64	48	86
3.281	24	32	28	64	3.582	44	40	28	86	3.840	64	40	24	100
3.300	44	64	48	100	3.588	72	56	24	86	3.840	32	40	48	100
3.300	44	32	24	100	3.600	72	48	24	100	3.850	44	64	56	100
3.308	32	72	64	86	3.600	72	64	32	100	3.850	28	32	44	100
3.333	32	64	48	72	3.600	72	56	28	100	3.876	24	72	100	86
3.333	28	56	48	72	3.600	48	32	24	100	3.889	32	64	56	72
3.333	28	48	32	56	3.618	56	72	40	86	3.889	56	48	24	72
3.345	28	100	86	72	3.636	24	44	32	48	3.889	24	24	28	72
3.349	40	86	72	100	3.636	28	44	32	56	3.896	24	44	40	56

TABLE OF LEADS, 3.907" TO 4.778"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
3.907	28	40	48	86	4.200	48	64	56	100	4.480	56	40	32	100
3.907	56	40	24	86	4.200	56	32	24	100	4.480	64	40	28	100
3.911	44	72	64	100	4.200	28	32	48	100	4.500	72	64	40	100
3.920	28	40	56	100	4.200	72	48	28	100	4.500	48	40	24	64
3.927	72	44	24	100	4.242	28	44	32	48	4.500	24	32	24	40
3.929	32	56	44	64	4.242	28	44	48	72	4.522	100	72	28	86
3.929	24	48	44	56						4.537	56	48	28	72
3.977	28	44	40	64	4.242	24	44	56	72	4.545	24	44	40	48
3.979	44	72	56	86	4.253	64	56	32	86	4.546	28	44	40	56
3.987	24	28	40	86	4.264	40	48	44	86	4.546	32	44	40	64
3.987	40	56	48	86	4.267	64	48	32	100	4.548	44	72	64	86
4.000	24	40	32	48	4.267	48	72	64	100	4.558	56	40	28	86
4.000	28	40	32	56	4.278	28	40	44	72	4.567	72	44	24	86
4.000	24	24	40	100	4.286	24	28	24	48	4.572	40	56	64	100
4.000	24	40	48	72	4.286	24	28	32	64	4.572	32	28	40	100
4.011	28	48	44	64	4.286	32	56	48	64	4.582	72	44	28	100
4.019	72	86	48	100	4.300	86	56	28	100	4.583	44	64	48	72
4.040	32	44	40	72	4.300	86	64	32	100	4.583	44	32	24	72
4.059	32	44	48	86	4.300	86	48	24	100	4.584	32	48	44	64
4.060	64	44	24	86	4.320	72	40	24	100	4.584	28	48	44	56
4.070	28	32	40	86	4.341	48	72	56	86	4.651	40	24	24	86
4.070	40	64	56	86	4.341	56	48	32	86	4.655	64	44	32	100
4.073	64	44	28	100	4.342	64	48	28	86	4.667	28	40	32	48
4.073	56	44	32	100	4.342	28	24	32	86	4.667	40	24	28	100
4.074	32	48	44	72	4.361	100	64	24	86	4.667	56	40	24	72
4.091	24	44	48	64	4.363	24	40	32	44	4.667	48	40	28	72
4.091	24	32	24	44	4.364	40	44	48	100	4.667	40	48	56	100
4.093	32	40	44	86	4.365	40	56	44	72	4.675	24	28	24	44
4.114	48	28	24	100	4.375	24	24	28	64	4.675	48	44	24	56
4.114	72	56	32	100	4.375	24	32	28	48	4.687	40	32	24	64
4.125	24	40	44	64	4.375	56	48	24	64	4.688	56	86	72	100
4.135	40	72	64	86	4.386	24	28	44	86	4.691	86	44	24	100
4.144	56	44	28	86	4.386	44	56	48	86	4.714	44	40	24	56
4.167	28	48	40	56	4.400	24	24	44	100	4.736	64	44	28	86
4.167	40	64	48	72	4.444	64	56	28	72	4.736	56	44	32	86
4.167	32	48	40	64	4.444	24	24	32	72	4.762	40	28	24	72
4.167	24	82	40	72	4.444	64	48	24	72	4.762	40	48	32	56
4.167	56	86	64	100	4.465	64	40	24	86	4.762	40	56	48	72
4.186	72	64	32	86	4.466	48	40	32	86	4.773	24	32	28	44
4.186	48	32	24	86	4.477	44	32	28	86	4.773	56	44	24	64
4.186	72	48	24	86	4.477	56	64	44	86	4.773	48	44	28	64
4.186	72	56	28	86	4.479	86	64	24	72	4.778	86	72	40	100

TABLE OF LEADS, 4.784" TO 5.733"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
4.784	72	56	32	86	5.116	44	24	24	86	5.358	64	86	72	100
4.785	48	28	24	86	5.119	86	56	24	72	5.375	86	64	40	100
4.800	48	24	24	100	5.120	64	40	32	100	5.400	72	32	24	100
4.800	56	28	24	100	5.133	56	48	44	100	5.400	72	64	48	100
4.800	64	32	24	100	5.134	44	24	28	100	5.413	64	44	32	86
4.800	72	48	32	100	5.142	72	56	40	100	5.426	40	24	28	86
4.813	44	40	28	64	5.143	24	28	24	40	5.427	40	48	56	86
4.821	72	56	24	64	5.143	24	40	48	56	5.444	56	40	28	72
4.849	32	44	48	72	5.156	44	32	24	64	5.455	48	44	28	56
4.849	64	44	24	72	5.160	86	40	24	100	5.455	32	44	48	64
4.861	40	32	28	72	5.168	100	72	32	86	5.469	40	32	28	64
4.861	56	64	40	72	5.185	28	24	32	72	5.473	86	44	28	100
4.884	48	64	56	86	5.186	64	48	28	72	5.486	64	28	24	100
4.884	72	48	28	86	5.186	56	48	32	72	5.486	48	28	32	100
4.884	48	32	28	86	5.195	32	44	40	56	5.486	48	56	64	100
4.884	56	32	24	86	5.209	100	64	24	72	5.500	44	40	24	48
4.889	32	40	44	72	5.210	64	40	28	86	5.500	44	40	32	64
4.898	24	28	32	56	5.210	56	40	32	86	5.500	40	32	44	100
4.900	56	32	28	100	5.226	86	64	28	72	5.500	44	40	28	56
4.911	40	56	44	64	5.233	72	64	40	86	5.556	40	24	24	72
4.914	86	56	32	100	5.236	72	44	32	100	5.568	56	44	28	64
4.950	56	44	28	72	5.238	44	28	24	72	5.581	64	32	24	86
4.950	72	64	44	100	5.238	32	48	44	56	5.581	56	28	24	86
4.961	64	48	32	86	5.238	44	56	48	72	5.581	72	48	32	86
4.961	64	72	48	86	5.250	24	32	28	40	5.582	48	24	24	86
4.978	56	72	64	100	5.250	56	40	24	64	5.600	56	24	24	100
4.984	100	56	24	86	5.250	48	40	28	64	5.600	48	24	28	100
5.000	24	24	28	56	5.256	86	72	44	100	5.600	64	32	28	100
5.000	24	24	32	64	5.280	48	40	44	100	5.625	48	32	24	64
5.000	48	32	24	72	5.303	28	44	40	48	5.625	72	48	24	64
5.017	86	48	28	100	5.316	40	28	32	86	5.625	72	56	28	64
5.023	72	40	24	86	5.316	40	56	64	86	5.657	56	44	32	72
5.029	44	28	32	100	5.328	72	44	28	86	5.657	72	56	44	100
5.029	64	56	44	100	5.333	40	24	32	100	5.657	64	44	28	72
5.040	72	40	28	100	5.333	64	40	24	72	5.698	56	32	28	86
5.074	40	44	48	86	5.333	32	40	48	72	5.714	48	28	24	72
5.080	64	56	32	72	5.333	40	48	64	100	5.714	24	28	32	48
5.088	100	64	28	86	5.347	44	64	56	72	5.714	24	24	32	56
5.091	56	44	40	100	5.348	44	32	28	72	5.714	64	48	24	56
5.091	28	40	32	44	5.357	40	28	24	64	5.730	40	48	44	64
5.093	40	48	44	72	5.357	40	32	24	56	5.733	86	48	32	100
5.105	28	48	56	64	5.357	40	56	48	64	5.733	86	72	48	100

TABLE OF LEADS, 5.756" TO 6.757"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
5.756	72	64	44	86	6.089	72	44	32	86	6.417	44	40	28	48
5.759	86	56	24	64	6.109	56	44	48	100	6.429	24	28	24	32
5.760	72	40	32	100	6.112	24	24	44	72	6.429	48	28	24	64
5.788	64	72	56	86	6.122	40	28	24	56	6.429	48	32	24	56
5.814	100	64	32	86	6.125	56	40	28	64	6.429	72	48	24	56
5.814	100	56	28	86	6.137	72	44	24	64	6.429	72	56	32	64
5.814	100	48	24	86	6.140	48	40	44	86	6.450	86	64	48	100
5.818	64	44	40	100	6.143	86	56	40	100	6.450	86	32	24	100
5.833	28	24	24	48	6.160	56	40	44	100	6.460	100	72	40	86
5.833	32	24	28	64						6.465	64	44	32	72
5.833	56	32	24	72	6.171	72	56	48	100	6.482	56	48	40	72
5.833	48	32	28	72	6.172	72	28	24	100	6.482	40	24	28	72
5.833	56	48	32	64	6.202	40	24	32	86	6.512	56	24	24	86
5.833	56	64	48	72	6.202	64	48	40	86	6.512	64	32	28	86
5.847	64	56	44	86	6.222	64	40	28	72	6.512	48	24	28	86
5.848	44	28	32	86	6.222	56	40	32	72	6.515	86	44	24	72
5.861	72	40	28	86	6.234	32	28	24	44	6.534	56	24	28	100
5.867	44	24	32	100	6.234	64	44	24	56	6.545	48	40	24	44
5.867	64	48	44	100	6.234	48	44	32	56	6.545	72	44	40	100
5.893	44	32	24	56	6.250	24	24	40	64	6.548	44	48	40	56
5.893	44	28	24	64	6.250	40	32	24	48	6.563	56	32	24	64
5.893	48	56	44	64	6.250	40	32	28	56	6.563	72	48	28	64
5.912	86	64	44	100	6.255	86	44	32	100	6.563	48	32	28	64
5.920	56	44	40	86	6.279	72	64	48	86	6.578	72	56	44	86
5.926	64	48	32	72	6.279	72	32	24	86	6.600	48	32	44	100
5.952	100	56	24	72	6.286	44	40	32	56	6.600	72	48	44	100
5.954	64	40	32	86	6.286	44	28	40	100	6.645	100	56	32	86
5.969	44	24	28	86	6.300	72	32	28	100	6.667	64	48	28	56
5.969	56	48	44	86	6.300	72	64	56	100	6.667	32	24	28	56
5.972	86	48	24	72	6.343	100	44	24	86	6.667	32	24	24	48
5.972	86	56	28	72	6.350	40	28	32	72	6.667	48	24	24	72
5.972	86	64	32	72	6.350	64	56	40	72	6.667	56	28	24	72
5.980	72	56	40	86	6.364	56	44	24	48	6.667	64	32	24	72
6.000	48	40	28	56	6.364	56	44	32	64	6.689	86	72	56	100
6.000	48	40	32	64	6.364	24	24	28	44	6.697	100	56	24	64
6.000	48	32	40	100	6.379	64	28	24	86	6.698	72	40	32	86
6.000	72	48	40	100	6.379	48	28	32	86	6.719	86	48	24	64
6.016	44	32	28	64	6.379	64	56	48	86	6.719	86	56	28	64
6.020	86	40	28	100	6.396	44	32	40	86	6.720	56	40	48	100
6.061	40	44	32	48	6.400	64	24	24	100	6.735	44	28	24	56
6.061	48	44	40	72	6.400	48	24	32	100	6.750	72	40	24	64
6.077	100	64	28	72	6.400	56	28	32	100	6.757	86	56	44	100

TABLE OF LEADS, 6.766" TO 7.883"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
6.766	64	44	40	86	7.159	72	44	28	64	7.525	86	32	28	100
6.784	100	48	28	86	7.163	56	40	44	86	7.525	86	64	56	100
6.806	56	32	28	72	7.167	86	40	24	72	7.543	48	28	44	100
6.818	40	32	24	44	7.167	86	48	40	100	7.576	100	44	24	72
6.818	48	44	40	64	7.176	72	28	24	86	7.597	56	24	28	86
6.822	44	24	32	86	7.176	72	56	48	86	7.601	86	44	28	72
6.822	64	48	44	86	7.200	72	24	24	100	7.611	72	44	40	86
6.825	86	56	32	72	7.268	100	64	40	86	7.619	64	48	32	56
6.857	32	28	24	40	7.272	64	44	28	56	7.619	64	56	48	72
6.857	64	40	24	56	7.273	32	24	24	44	7.620	64	28	24	72
6.857	48	40	32	56	7.273	64	44	24	48	7.620	48	28	32	72
6.857	48	28	40	100	7.292	56	48	40	64	7.636	56	40	24	44
6.875	44	24	24	64	7.292	40	32	28	48	7.636	48	40	28	44
6.875	44	32	24	48	7.292	40	24	28	64	7.639	44	32	40	72
6.875	44	32	28	56	7.310	44	28	40	86	7.644	86	72	64	100
6.880	86	40	32	100	7.314	64	28	32	100	7.657	56	32	28	64
6.944	100	48	24	72	7.325	72	32	28	86	7.674	72	48	44	86
6.944	100	64	32	72	7.326	72	64	56	86	7.675	48	32	44	86
6.945	100	56	28	72	7.330	86	44	24	64	7.679	86	48	24	56
6.968	86	48	28	72	7.333	44	24	40	100	7.679	86	56	32	64
6.977	48	32	40	86	7.333	48	40	44	72	7.680	64	40	48	100
6.977	100	40	24	86	7.334	44	40	32	48	7.700	56	32	44	100
6.977	72	48	40	86	7.347	48	28	24	56	7.714	72	40	24	56
6.982	64	44	48	100	7.371	86	56	48	100	7.752	100	48	32	86
6.984	44	28	32	72	7.372	86	28	24	100	7.752	100	72	48	86
6.984	64	56	44	72	7.400	100	44	28	86	7.778	32	24	28	48
7.000	28	24	24	40	7.408	40	24	32	72	7.778	56	24	24	72
7.000	56	40	24	48	7.408	64	48	40	72	7.778	48	24	28	72
7.000	56	40	32	64	7.424	56	44	28	48	7.778	64	32	28	72
7.000	56	32	40	100	7.442	64	24	24	86	7.792	40	28	24	44
7.013	72	44	24	56	7.442	48	24	32	86	7.792	48	44	40	56
7.040	64	40	44	100	7.442	56	28	32	86	7.813	100	48	24	64
7.071	56	44	40	72	7.465	86	64	40	72	7.813	100	56	28	64
					7.467	64	24	28	100	7.815	56	40	48	86
7.104	56	44	48	86						7.818	86	44	40	100
7.106	100	72	44	86	7.467	56	24	32	100	7.838	86	48	28	64
7.111	64	40	32	72	7.467	64	48	56	100	7.855	72	44	48	100
7.130	44	24	28	72	7.500	48	24	24	64	7.857	44	24	24	56
7.130	56	48	44	72	7.500	56	28	24	64	7.857	44	28	24	48
7.143	40	28	32	64	7.500	48	32	28	56	7.872	44	28	32	64
7.143	40	28	24	48	7.500	72	48	28	56	7.875	72	40	28	64
7.143	40	24	24	56	7.500	72	48	32	64	7.883	86	48	44	100

TABLE OF LEADS, 7.920" TO 9.302"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
7.920	72	40	44	100	8.333	48	32	40	72	8.772	48	28	44	86
7.936	100	56	32	72	8.333	100	40	24	72	8.800	48	24	44	100
7.954	40	32	28	44	8.334	40	24	28	56	8.800	64	32	44	100
7.955	56	44	40	64	8.361	86	40	28	72	8.800	56	28	44	100
7.963	86	48	32	72	8.372	72	24	24	86	8.838	100	44	28	72
7.974	48	28	40	86	8.377	86	44	24	56	8.839	72	56	44	64
7.994	100	64	44	86	8.400	72	24	28	100	8.889	64	24	24	72
8.000	64	32	40	100	8.400	56	32	48	100	8.889	56	28	32	72
8.000	32	24	24	40	8.400	72	48	56	100	8.889	48	24	32	72
8.000	64	40	24	48	8.437	72	32	24	64	8.909	56	40	28	44
8.000	64	40	28	56	8.457	100	44	32	86	8.929	100	48	24	56
8.000	56	28	40	100	8.484	32	24	28	44	8.929	100	56	32	64
8.000	48	24	40	100	8.485	64	44	28	48	8.930	64	40	48	86
8.021	44	32	28	48	8.485	56	44	32	48	8.953	56	32	44	86
8.021	44	24	28	64	8.485	56	44	48	72	8.959	86	48	28	56
8.021	56	48	44	64	8.506	64	28	32	86	8.959	86	32	24	72
8.035	72	56	40	64	8.523	100	44	24	64	8.959	86	64	48	72
8.063	86	40	24	64	8.527	44	24	40	86	8.959	86	48	28	56
8.081	64	44	40	72	8.532	86	56	40	72	8.960	64	40	56	100
8.102	100	48	28	72	8.534	64	24	32	100	8.980	44	28	32	56
8.119	64	44	48	86	8.552	86	44	28	64	9.000	48	32	24	40
8.140	56	32	40	86	8.556	56	40	44	72	9.000	72	40	24	48
8.140	100	40	28	86	8.572	64	32	24	56	9.000	72	40	28	56
8.145	64	44	56	100	8.572	48	28	32	64	9.000	72	40	32	64
8.148	64	48	44	72	8.572	48	24	24	56	9.000	72	32	40	100
8.149	44	24	32	72	8.572	72	48	32	56	9.044	100	72	56	86
8.163	40	28	32	56	8.594	44	32	40	64	9.074	56	24	28	72
8.167	56	40	28	48	8.600	86	24	24	100	9.091	40	24	24	44
8.182	48	32	24	44	8.640	72	40	48	100	9.115	100	48	28	64
8.182	72	44	24	48	8.681	100	64	40	72	9.134	72	44	48	86
8.182	72	44	28	56	8.682	64	24	28	86	9.137	100	56	44	86
8.182	72	44	32	64	8.682	56	24	32	86	9.143	64	40	32	56
8.186	64	40	44	86	8.682	64	48	56	86	9.143	64	28	40	100
8.212	86	64	44	72	8.687	86	44	32	72	9.164	72	44	56	100
8.229	72	28	32	100	8.721	100	32	24	86	9.167	44	24	24	48
8.229	72	56	64	100	8.721	100	64	48	86	9.167	44	24	28	56
8.250	44	32	24	40	8.727	48	40	32	44	9.167	44	24	32	64
8.250	48	40	44	64	8.730	44	28	40	72	9.167	48	32	44	72
8.306	100	56	40	86	8.750	28	24	24	32	9.210	72	40	44	86
8.312	64	44	32	56	8.750	56	32	24	48	9.214	86	40	24	56
8.333	40	24	24	48	8.750	56	24	24	64	9.260	100	48	32	72
8.333	40	24	32	64	8.750	48	24	28	64	9.302	48	24	40	86

TABLE OF LEADS, 9.303" TO 10.477"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
9.303	56	28	40	86	9.675	86	64	72	100	10.101	100	44	32	72
9.303	64	32	40	86	9.690	100	48	40	86	10.159	64	28	32	72
9.303	100	40	32	86	9.697	64	48	32	44	10.175	100	32	28	86
9.333	64	40	28	48	9.697	64	44	48	72	10.175	100	64	56	86
9.333	56	40	32	48	9.723	40	24	28	48	10.182	64	40	28	44
9.333	56	24	40	100	9.723	56	32	40	72	10.182	56	40	32	44
9.333	56	40	48	72	9.723	100	40	28	72	10.186	44	24	40	72
9.334	32	24	28	40	9.741	100	44	24	56	10.209	56	24	28	64
9.351	48	28	24	44	9.768	72	48	56	86	10.209	56	32	28	48
9.351	72	44	32	56	9.768	56	32	48	86	10.228	72	44	40	64
9.375	48	32	40	64	9.768	72	24	28	86	10.233	48	24	44	86
9.375	100	40	24	64	9.773	86	44	24	48	10.233	56	28	44	86
9.375	72	48	40	64	9.773	86	44	28	56	10.233	64	32	44	86
9.382	86	44	48	100	9.773	86	44	32	64	10.238	86	28	24	72
9.385	86	56	44	72	9.778	64	40	44	72	10.238	86	48	32	56
9.406	86	40	28	64	9.796	64	28	24	56	10.238	86	56	48	72
9.428	44	28	24	40	9.796	48	28	32	56	10.267	56	24	44	100
9.429	48	40	44	56	9.818	72	40	24	44	10.286	48	28	24	40
9.460	86	40	44	100	9.822	44	32	40	56	10.286	72	40	32	56
9.472	64	44	56	86	9.822	44	28	40	64	10.286	72	28	40	100
9.524	40	28	32	48	9.828	86	28	32	100	10.312	48	32	44	64
9.524	40	24	32	56	9.828	86	56	64	100	10.313	72	48	44	64
9.524	48	28	40	72	9.844	72	32	28	64	10.320	86	40	48	100
9.524	64	48	40	56	9.900	72	32	44	100	10.336	100	72	64	86
9.545	72	44	28	48	9.921	100	56	40	72	10.370	64	24	28	72
9.546	56	32	24	44	9.923	64	24	32	86	10.370	56	24	32	72
9.546	48	32	28	44	9.943	100	44	28	64	10.371	64	48	56	72
9.547	56	44	48	64	9.954	86	48	40	72	10.390	40	28	32	44
9.549	100	64	44	72	9.967	100	56	48	86	10.390	64	44	40	56
9.556	86	40	32	72	9.968	100	28	24	86	10.417	100	32	24	72
9.569	72	28	32	86	10.000	56	28	24	48	10.417	100	48	28	56
9.569	72	56	64	86	10.000	48	24	28	56	10.417	100	48	32	64
9.598	86	56	40	64	10.000	64	32	24	48	10.417	100	64	48	72
9.600	72	24	32	100	10.000	64	32	28	56	10.419	64	40	56	86
9.600	56	28	48	100	10.000	56	28	32	64	10.451	86	32	28	72
9.600	64	32	48	100	10.000	48	24	32	64	10.451	86	64	56	72
9.600	72	48	64	100	10.033	86	24	28	100	10.467	72	32	40	86
9.625	44	32	28	40	10.033	86	48	56	100	10.473	72	44	64	100
9.625	56	40	44	64	10.046	72	40	48	86	10.476	44	24	32	56
9.643	72	32	24	56	10.057	64	28	44	100	10.476	44	28	32	48
9.643	72	28	24	64	10.078	86	32	24	64	10.477	48	28	44	72
9.643	72	56	48	64	10.080	72	40	56	100	10.477	64	48	44	56

TABLE OF LEADS, 10.500" TO 12.272"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
10.500	56	32	24	40	11.111	48	24	40	72	11.667	64	32	28	48
10.500	48	32	28	40	11.111	56	28	40	72	11.667	56	32	48	72
10.500	72	40	28	48	11.111	64	32	40	72	11.667	56	24	32	64
10.500	56	40	48	64	11.111	100	40	32	72	11.688	72	44	40	56
10.558	86	56	44	64	11.137	56	32	28	44	11.695	64	28	44	86
10.571	100	44	40	86	11.160	100	56	40	64	11.719	100	32	24	64
10.606	56	44	40	48	11.163	72	24	32	86	11.721	72	40	56	86
10.606	40	24	28	44	11.163	56	28	48	86	11.728	86	40	24	44
10.631	64	28	40	86	11.163	72	48	64	86	11.733	64	24	44	100
10.655	72	44	56	86	11.163	64	32	48	86	11.757	86	32	28	64
10.659	100	48	44	86	11.169	86	44	32	56	11.785	72	48	44	56
10.667	64	40	48	72	11.198	86	48	40	64	11.786	44	28	24	32
10.667	64	24	40	100	11.200	56	24	48	100	11.786	48	32	44	56
10.667	64	40	32	48	11.200	64	32	56	100	11.786	48	28	44	64
10.694	44	24	28	48	11.225	44	28	40	56	11.825	86	32	44	100
10.694	56	32	44	72	11.250	72	24	24	64	11.852	64	24	32	72
10.713	40	28	24	32	11.250	72	32	24	48	11.905	100	28	24	72
10.714	48	32	40	56	11.250	72	32	28	56	11.905	100	48	32	56
10.714	48	28	40	64	11.313	64	44	56	72	11.905	100	56	48	72
10.714	100	40	24	56	11.314	72	28	44	100	11.938	56	24	44	86
10.714	72	48	40	56	11.363	100	44	24	48	11.944	86	24	24	72
10.750	86	40	24	48	11.363	100	44	28	56	11.960	72	28	40	86
10.750	86	40	28	56	11.363	100	44	32	64	12.000	48	24	24	40
10.750	86	40	32	64	11.401	86	44	28	48	12.000	56	28	24	40
10.750	86	32	40	100	11.429	32	24	24	28	12.000	64	32	24	40
10.800	72	32	48	100	11.429	64	28	24	48	12.000	72	40	32	48
10.853	56	24	40	86	11.429	64	24	24	56	12.000	72	24	40	100
10.859	86	44	40	72	11.429	48	24	32	56	12.031	56	32	44	64
10.909	72	44	32	48	11.454	72	40	28	44	12.040	86	40	56	100
10.909	56	28	24	44	11.459	44	24	40	64	12.121	40	24	32	44
10.909	48	24	24	44	11.459	44	32	40	48	12.121	64	44	40	48
10.909	64	32	24	44	11.467	86	24	32	100	12.153	100	32	28	72
10.913	100	56	44	72	11.467	86	48	64	100	12.153	100	64	56	72
10.937	56	32	40	64	11.512	72	32	44	86	12.178	72	44	64	86
10.937	100	40	28	64	11.518	86	28	24	64	12.216	86	44	40	64
10.945	86	44	56	100	11.518	86	32	24	56	12.222	44	24	32	48
10.949	86	48	44	72	11.518	86	56	48	64	12.222	48	24	44	72
10.972	64	28	48	100	11.520	72	40	64	100	12.222	56	28	44	72
11.000	44	24	24	40	11.574	100	48	40	72	12.222	64	32	44	72
11.021	72	28	24	56	11.629	100	24	24	86	12.245	48	28	40	56
11.057	86	56	72	100	11.638	64	40	32	44	12.250	56	32	28	40
11.111	40	24	32	48	11.667	56	24	24	48	12.272	72	32	24	44

TABLE OF LEADS, 12.272" TO 14.322"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
12.272	72	44	48	64	12.900	86	32	48	100	13.566	100	48	56	86
12.277	100	56	44	64	12.900	86	48	72	100	13.611	56	24	28	48
12.286	86	28	40	100	12.963	56	24	40	72	13.636	48	32	40	44
12.286	86	40	32	56	12.987	100	44	32	56	13.636	100	40	24	44
12.318	86	48	44	64	13.020	100	48	40	64	13.636	72	44	40	48
12.343	72	28	48	100	13.024	56	24	48	86	13.643	64	24	44	86
12.375	72	40	44	64	13.024	64	32	56	86	13.650	86	28	32	72
12.403	64	24	40	86	13.030	86	44	32	48	13.650	86	56	64	72
12.444	64	40	56	72	13.030	86	44	48	72	13.672	100	32	28	64
12.468	64	28	24	44	13.062	64	28	32	56	13.682	86	40	28	44
12.468	48	28	32	44	13.082	100	64	72	86	13.713	64	40	48	56
12.468	64	44	48	56	13.090	72	40	32	44	13.715	64	28	24	40
12.500	40	24	24	32	13.096	44	28	40	48	13.715	48	28	32	40
12.500	48	24	40	64	13.096	44	24	40	56	13.750	44	24	24	32
12.500	56	28	40	64	13.125	72	32	28	48	13.750	48	24	44	64
12.500	100	40	24	48	13.125	72	24	28	64	13.750	56	28	44	64
12.500	100	40	28	56	13.125	56	32	48	64	13.760	86	40	64	100
12.500	100	40	32	64	13.125	72	48	56	64	13.889	100	24	24	72
12.542	86	40	28	48	13.139	86	40	44	72	13.933	86	48	56	72
12.508	86	44	64	100	13.157	72	28	44	86	13.935	86	24	28	72
12.558	72	32	48	86	13.163	86	28	24	56	13.953	72	24	40	86
12.571	64	40	44	56	13.200	72	24	44	100	13.953	100	40	48	86
12.572	44	28	32	40	13.258	100	44	28	48	13.960	86	44	40	56
12.600	72	32	56	100	13.289	100	28	32	86	13.968	64	28	44	72
12.627	100	44	40	72	13.289	100	56	64	86	14.000	56	24	24	40
12.686	100	44	48	86	13.333	64	24	24	48	14.000	48	24	28	40
12.698	64	28	40	72	13.333	64	24	28	56	14.000	64	32	28	40
12.727	64	32	28	44	13.333	56	28	32	48	14.025	72	44	48	56
12.728	56	24	24	44	13.333	56	28	48	72	14.026	72	28	24	44
12.728	48	24	28	44	13.333	64	32	48	72	14.063	72	32	40	64
12.732	100	48	44	72	13.393	100	56	48	64	14.071	86	44	72	100
12.758	64	28	48	86	13.393	100	28	24	64	14.078	86	48	44	56
12.791	100	40	44	86	13.393	100	32	24	56	14.142	72	40	44	56
12.798	86	48	40	56	13.396	72	40	64	86	14.204	100	44	40	64
12.800	64	28	56	100	13.437	86	32	28	56	14.260	56	24	44	72
12.800	64	24	48	100	13.438	86	24	24	64	14.286	40	24	24	28
12.834	56	40	44	48	13.438	86	32	24	48	14.286	48	24	40	56
12.834	44	24	28	40	13.469	48	28	44	56	14.286	64	32	40	56
12.857	72	28	32	64	13.500	72	32	24	40	14.286	100	40	32	56
12.857	72	24	24	56	13.500	72	40	48	64	14.318	72	32	28	44
12.857	72	28	24	48	13.514	86	28	44	100	14.319	72	44	56	64
12.858	48	28	24	32	13.566	100	24	28	86	14.322	100	48	44	64

TABLE OF LEADS, 14.333" TO 16.914"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
14.333	86	40	32	48	15.238	64	28	48	72	15.989	100	32	44	86
14.333	86	24	40	100	15.239	64	28	32	48	16.000	64	24	24	40
14.333	86	40	48	72	15.239	64	24	32	56	16.000	48	24	32	40
14.352	72	28	48	86	15.272	56	40	48	44	16.000	56	28	32	40
14.400	72	24	48	100	15.278	44	24	40	48	16.042	56	24	44	64
14.400	72	28	56	100	15.279	100	40	44	72	16.042	56	32	44	48
14.400	72	32	64	100	15.306	100	28	24	56	16.043	44	24	28	32
14.536	100	32	40	86	15.349	72	24	44	86	16.071	72	32	40	56
14.545	64	24	24	44	15.357	86	28	24	48	16.071	72	28	40	64
14.545	48	24	32	44	15.357	86	24	24	56	16.125	86	32	24	40
14.545	56	28	32	44	15.357	86	28	32	64	16.125	86	40	48	64
14.583	56	32	40	48	15.429	72	40	48	56	16.204	100	24	28	72
14.583	56	24	40	64	15.429	72	28	24	40	16.204	100	48	56	72
14.583	100	40	28	48	15.469	72	32	44	64	16.233	100	44	40	56
14.584	40	24	28	32	15.480	86	40	72	100	16.280	100	40	56	86
14.651	72	32	56	86	15.504	100	48	64	86	16.288	86	44	40	48
14.659	86	44	48	64	15.504	100	24	32	86	16.296	64	24	44	72
14.659	86	32	24	44	15.556	64	32	56	72	16.327	64	28	40	56
14.667	64	40	44	48	15.556	64	24	28	48	16.333	56	24	28	40
14.668	44	24	32	40	15.556	56	24	32	48	16.364	72	24	24	44
14.694	72	28	32	56	15.556	32	24	28	24	16.370	100	48	44	56
14.743	86	28	48	100	15.556	56	24	48	72	16.423	86	32	44	72
14.780	86	40	44	64	15.584	48	28	40	44	16.456	72	28	64	100
14.800	100	44	56	86	15.625	100	24	24	64	16.500	72	40	44	48
14.815	64	24	40	72	15.625	100	32	24	48	16.500	48	32	44	40
14.849	56	24	28	44	15.625	100	32	28	56	16.612	100	28	40	86
14.880	100	48	40	56	15.636	86	40	32	44	16.623	64	28	32	44
14.884	64	28	56	86	15.677	86	32	28	48	16.667	56	28	40	48
14.884	64	24	48	86	15.677	86	24	28	64	16.667	64	32	40	48
14.931	86	32	40	72	15.677	86	48	56	64	16.667	100	40	32	48
14.933	64	24	56	100	15.714	44	24	24	28	16.667	100	40	48	72
14.950	100	56	72	86	15.714	48	24	44	56	16.722	86	40	56	72
15.000	48	24	24	32	15.714	64	32	44	56	16.744	72	24	48	86
15.000	56	28	24	32	15.750	72	32	28	40	16.744	72	28	56	86
15.000	72	24	24	48	15.750	72	40	56	64	16.744	72	32	64	86
15.000	72	24	28	56	15.767	86	24	44	100	16.752	86	44	48	56
15.000	72	24	32	64	15.873	100	56	64	72	16.753	86	28	24	44
15.000	56	28	48	64	15.874	100	28	32	72	16.797	86	32	40	64
15.050	86	32	56	100	15.909	100	40	28	44	16.800	72	24	56	100
15.150	100	44	32	48	15.909	56	32	40	44	16.875	72	32	48	64
15.151	100	44	48	72	15.925	86	48	64	72	16.892	86	40	44	56
15.202	86	44	56	72	15.926	86	24	32	72	16.914	100	44	64	86

TABLE OF LEADS, 16.969" TO 20.20"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
16.969	64	44	56	48	17.918	86	32	48	72	19.091	72	24	28	44
16.970	64	24	28	44	17.959	64	28	44	56	19.096	100	32	44	72
16.970	56	24	32	44	18.000	72	24	24	40	19.111	86	40	64	72
17.045	100	32	24	44	18.181	56	28	40	44	19.136	72	28	64	86
17.046	100	44	48	64	18.181	64	32	40	44	19.197	86	32	40	56
17.062	86	28	40	72	18.181	100	40	32	44	19.197	86	28	40	64
17.101	86	44	56	64	18.182	48	24	40	44	19.200	72	24	64	100
17.102	86	32	28	44	18.229	100	32	28	48	19.250	56	32	44	40
17.141	64	32	48	56	18.229	100	24	28	64	19.285	72	32	48	56
17.143	64	28	24	32	18.229	100	48	56	64	19.285	72	28	48	64
17.144	48	24	24	28	18.273	100	28	44	86	19.286	72	28	24	32
17.144	72	28	32	48	18.285	64	28	32	40	19.350	86	32	72	100
17.144	72	24	32	56	18.333	56	28	44	48	19.380	100	24	40	86
17.144	72	48	64	56	18.333	64	32	44	48	19.394	64	24	32	44
17.188	100	40	44	64	18.367	72	28	40	56	19.444	40	24	28	24
17.200	86	32	64	100	18.428	86	28	24	40	19.444	56	24	40	48
17.200	86	28	56	100	18.428	86	40	48	56	19.444	100	40	56	72
17.200	86	24	48	100	18.476	86	32	44	64	19.480	100	28	24	44
17.275	86	56	72	64	18.519	100	24	32	72	19.480	100	44	48	56
17.361	100	32	40	72	18.519	100	48	64	72	19.531	100	32	40	64
17.364	64	24	56	86	18.605	100	40	64	86	19.535	72	24	56	86
17.373	86	44	64	72	18.663	100	64	86	72	19.545	86	24	24	44
17.442	100	32	48	86	18.667	64	24	28	40	19.590	64	28	48	56
17.442	100	48	72	86	18.667	56	24	32	40	19.635	72	40	48	44
17.454	64	40	48	44	18.667	64	40	56	48	19.642	100	40	44	56
17.500	56	24	24	32	18.700	72	44	64	56	19.643	44	28	40	32
17.500	48	24	28	32	18.700	72	28	32	44	19.656	86	28	64	100
17.500	72	24	28	48	18.750	100	32	24	40	19.687	72	32	56	64
17.500	56	24	48	64	18.750	72	24	40	64	19.710	86	40	44	48
17.550	86	28	32	56	18.750	72	32	40	48	19.840	100	28	40	72
17.677	100	44	56	72	18.750	100	40	48	64	19.886	100	44	56	64
17.679	72	32	44	55	18.770	86	28	44	72	19.887	100	32	28	44
17.679	72	28	44	64	18.812	86	32	28	40	19.908	86	24	40	72
17.778	64	24	32	48	18.812	86	40	56	64	19.934	100	28	48	86
17.778	64	24	48	72	18.858	48	28	44	40	20.00	72	24	32	48
17.778	64	28	56	72	18.939	100	44	40	48	20.00	64	24	24	32
17.858	100	24	24	56	19.029	100	44	72	86	20.00	56	24	24	28
17.858	100	28	32	64	19.048	40	24	32	28	20.07	86	24	56	100
17.858	100	28	24	48	19.048	64	24	40	56	20.09	100	56	72	64
17.917	86	24	32	64	19.048	64	28	40	48	20.16	86	48	72	64
17.917	86	24	28	56	19.090	56	32	48	44	20.16	86	32	48	64
17.918	86	24	24	48	19.090	72	44	56	48	20.20	100	44	64	72

TABLE OF LEADS, 20.20" TO 24.55"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
20.20	72	28	44	56	21.43	100	28	24	40	23.04	86	32	48	56
20.20	72	28	44	56	21.48	100	32	44	64	23.04	86	28	48	64
20.35	100	32	56	86	21.50	86	24	24	40	23.04	86	28	24	32
20.36	64	40	56	44	21.82	72	44	64	48	23.14	100	24	40	72
20.41	100	28	32	56	21.82	100	28	44	72	23.26	100	32	64	86
20.42	56	24	28	32	21.82	64	32	48	44	23.26	100	28	56	86
20.45	72	32	40	44	21.82	56	28	48	44	23.26	100	24	48	86
20.48	86	48	64	56	21.82	72	24	32	44	23.33	64	32	56	48
20.48	86	28	48	72	21.88	100	40	56	64	23.33	48	24	28	24
20.48	86	28	32	48	21.88	100	32	28	40	23.33	64	24	28	32
20.48	86	24	32	56	21.90	86	24	44	72	23.38	72	28	40	44
20.57	72	40	64	56	21.94	86	28	40	56	23.44	100	48	72	64
20.57	72	28	32	40	21.99	86	44	72	64	23.44	100	32	48	64
20.63	72	32	44	48	22.00	64	32	44	40	23.45	86	40	48	44
20.63	72	24	44	64	22.00	48	24	44	40	23.52	86	32	56	64
20.74	64	24	56	72	22.00	56	28	44	40	23.57	72	28	44	48
20.78	64	28	40	44	22.04	72	28	48	56	23.57	72	24	44	56
20.83	100	32	48	72	22.11	86	28	72	100	23.57	48	28	44	32
20.83	100	24	32	64	22.22	100	40	64	72					
20.83	100	24	28	56	22.22	40	24	32	24	23.81	100	48	64	56
20.83	100	24	24	48	22.22	64	24	40	48	23.81	100	28	48	72
20.90	86	32	56	72	22.32	72	24	64	86	23.81	100	28	32	48
20.90	86	24	28	48	22.32	100	32	40	56	23.81	100	24	32	56
20.93	100	40	72	86	22.32	100	28	40	64	23.89	86	32	64	72
20.95	64	28	44	48	22.34	86	44	64	56	23.89	86	28	56	72
20.95	64	24	44	56	22.34	86	28	32	44	23.89	86	24	48	72
20.95	44	24	32	28	22.40	86	32	40	48	23.89	86	24	32	48
21.00	56	32	48	40	22.40	86	24	40	64	24.00	64	40	72	48
21.00	72	40	56	48	22.50	72	24	48	64	24.00	72	24	32	40
21.00	72	24	28	40	22.50	72	24	24	32	24.00	56	28	48	40
21.12	86	32	44	56	22.50	72	28	56	64	24.00	64	32	48	40
21.12	86	28	44	64	22.73	100	24	24	44	24.00	100	56	86	64
21.21	56	24	40	44	22.80	86	48	56	44	24.13	86	28	44	56
21.32	100	24	44	86	22.80	86	24	28	44	24.19	86	40	72	64
21.33	100	56	86	72	22.86	64	24	24	28	24.24	64	24	40	44
21.33	64	24	32	40	22.86	48	24	32	28	24.31	100	32	56	72
21.39	44	24	28	24	22.86	64	24	48	56	24.31	100	24	28	48
21.39	56	24	44	48	22.91	72	44	56	40	24.43	86	32	40	44
21.43	100	40	48	56	22.92	100	40	44	48	24.44	44	24	32	24
21.43	72	28	40	48	22.92	44	24	40	32	24.44	64	24	44	48
21.43	72	24	40	56	22.93	86	24	64	100	24.54	72	32	48	44
21.43	48	28	40	32	23.04	86	56	72	48	24.55	100	32	44	56

TABLE OF LEADS, 24.55" TO 31.11"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
24.55	100	28	44	64	26.52	100	24	28	44	28.57	100	56	64	40
24.57	86	40	64	56	26.53	100	28	64	86	28.57	48	28	40	24
24.57	86	28	32	40	26.67	64	28	56	48	28.57	64	32	40	28
24.64	86	24	44	64	26.67	56	24	32	28	28.57	100	28	32	40
24.64	86	32	44	48	26.67	48	24	32	24	28.64	72	44	56	32
24.75	72	32	44	40	26.79	100	48	72	56	28.65	100	32	44	48
24.88	100	72	86	48	26.79	100	32	48	56	28.65	100	24	44	64
24.93	64	28	48	44	26.79	100	28	48	64	28.67	86	40	64	48
25.00	72	24	40	48	26.79	100	28	24	32	28.67	86	24	32	40
25.00	48	24	40	32	26.88	86	28	56	64	29.09	64	24	48	44
25.00	56	28	40	32	26.88	86	24	48	64	29.09	64	28	56	44
25.00	100	24	24	40	26.88	86	24	24	32	29.17	100	40	56	48
25.08	86	24	28	40	27.00	72	32	48	40	29.17	56	24	40	32
25.09	86	40	56	48	27.13	100	24	56	86	29.17	100	24	28	40
25.13	86	44	72	56	27.15	100	44	86	72	29.22	100	56	72	44
25.14	64	28	44	40	27.22	56	24	28	24	29.32	86	48	72	44
25.45	64	44	56	32	27.27	100	40	48	44	29.32	86	32	48	44
25.45	56	24	48	44	27.27	72	24	40	44	29.34	64	24	44	40
25.46	100	24	44	72	27.30	86	28	64	72	29.39	72	28	64	56
25.51	100	28	40	56	27.34	100	32	56	64	29.56	86	32	44	40
25.57	100	64	72	44	27.36	86	40	56	44	29.76	100	28	40	48
25.60	86	28	40	48	27.43	64	28	48	40	29.76	100	24	40	56
25.60	86	24	40	56	27.50	56	32	44	28	29.86	100	40	86	72
25.67	56	24	44	40	27.50	48	24	44	32	29.86	86	24	40	48
25.71	72	24	48	56	27.50	72	24	44	48	29.90	100	28	72	86
25.71	72	56	64	32	27.64	86	40	72	56	30.00	56	28	48	32
25.72	72	24	24	28	27.78	100	32	64	72	30.00	72	32	64	48
25.80	86	24	72	100	27.78	100	28	56	72	30.00	72	28	56	48
25.97	100	44	64	56	27.78	100	24	48	72	30.23	86	32	72	64
25.97	100	28	32	44	27.78	100	24	32	48	30.30	100	48	64	44
26.04	100	32	40	48	27.87	86	24	56	72	30.30	100	24	32	44
26.04	100	24	40	64	27.92	86	28	40	44	30.48	64	24	32	28
26.06	86	44	64	48	28.00	100	64	86	48	30.54	100	44	86	64
26.06	86	24	32	44	28.00	64	32	56	40	30.56	44	24	40	24
26.16	100	32	72	86	28.00	56	24	48	40	30.61	100	28	48	56
26.18	72	40	64	44	28.05	72	28	48	44	30.71	86	24	48	56
26.19	44	24	40	28	28.06	100	28	44	56	30.71	86	32	64	56
26.25	72	32	56	48	28.13	100	40	72	64	30.72	86	24	24	28
26.25	72	24	56	64	28.15	86	28	44	48	30.86	72	28	48	40
26.25	72	24	28	32	28.15	86	24	44	56	31.01	100	24	64	86
26.33	86	28	48	56	28.29	72	28	44	40	31.11	64	24	56	48
26.52	100	44	56	48	28.41	100	32	40	44	31.11	56	24	32	24

TABLE OF LEADS, 31.11" TO 41.99"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
31.11	64	24	28	24	34.09	100	44	48	32	37.50	72	24	40	32
31.25	100	28	56	64	34.20	86	44	56	32	37.63	86	32	56	40
31.25	100	24	48	64	34.29	72	48	64	28	37.88	100	24	40	44
31.25	100	24	24	32	34.29	72	24	64	56	38.10	64	24	40	28
31.27	86	40	64	44	34.29	64	32	48	28	38.18	72	24	56	44
31.35	86	32	56	48	34.29	72	24	32	28	38.20	100	24	44	48
31.35	86	24	56	64	34.38	100	32	44	40	38.39	100	40	86	56
31.36	86	24	28	32	34.55	86	32	72	56	38.39	86	28	40	32
31.43	64	28	44	32	34.55	86	28	72	64	38.57	72	28	48	32
31.43	48	24	44	28	34.72	100	24	40	48	38.89	56	24	40	24
31.50	72	32	56	40	34.88	100	24	72	86	38.96	100	28	48	44
31.75	100	72	64	28	34.90	100	56	86	44	39.09	86	32	64	44
31.82	100	44	56	40	35.00	72	24	56	48	39.09	86	28	56	44
31.85	86	24	64	72	35.00	56	24	48	32	39.09	86	24	48	44
31.99	100	56	86	48	35.00	72	24	28	24	39.29	100	28	44	40
32.00	64	28	56	40	35.10	86	28	64	56	39.42	86	24	44	40
32.00	64	24	48	40	35.16	100	32	72	64					
32.09	56	24	44	32	35.18	86	44	72	40	39.49	86	28	72	56
32.14	100	56	72	40	35.36	72	32	44	28	39.77	100	32	56	44
32.14	72	28	40	32	35.56	64	24	32	24	40.00	72	24	64	48
32.25	86	48	72	40	35.71	100	32	64	56	40.00	64	28	56	32
32.25	86	40	48	32	35.71	100	24	48	56	40.00	64	24	48	32
32.41	100	24	56	72	35.72	100	24	24	28	40.00	56	24	48	28
32.47	100	28	40	44	35.83	86	32	64	48	40.00	72	24	32	24
32.58	86	24	40	44	35.83	86	28	56	48	40.18	100	32	72	56
32.73	72	32	64	44	36.00	72	32	64	40	40.18	100	28	72	64
32.73	72	28	56	44	36.00	72	28	56	40	40.31	86	32	72	48
32.73	72	24	48	44	36.00	72	24	48	40	40.31	86	24	72	64
32.74	100	28	44	48	36.36	100	44	64	40	40.72	100	44	86	48
32.74	100	24	44	56	36.46	100	48	56	32	40.82	100	28	64	56
32.85	86	24	44	48	36.46	100	24	56	64	40.91	100	40	72	44
33.00	72	24	44	40	36.46	100	24	28	32	40.95	86	28	64	48
33.33	100	24	32	40	36.67	48	24	44	24	40.95	86	24	64	56
33.33	100	48	64	40	36.67	64	24	44	32	40.96	86	24	32	28
33.33	64	24	40	32	36.67	56	24	44	28	41.14	72	28	64	40
33.33	56	24	40	28	36.86	86	28	48	40	41.25	72	24	44	32
33.33	48	24	40	24	37.04	100	24	64	72	41.67	100	32	64	48
33.51	86	28	48	44	37.33	100	32	86	72	41.67	100	28	56	48
33.59	100	64	86	40	37.33	64	24	56	40	41.81	86	24	56	48
33.79	86	28	44	40	37.40	72	28	64	44	41.81	86	24	28	24
33.94	64	24	56	44	37.50	100	48	72	40	41.91	64	24	44	28
34.09	100	48	72	44	37.50	100	32	48	40	41.99	100	32	86	64

TABLE OF LEADS, 42.00" TO 74.65"

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1 ST GEAR ON STUD	2 ND GEAR ON STUD	GEAR ON SCREW
42.00	72	24	56	40	48.00	72	24	64	40	50.31	86	24	44	28
					48.38	86	32	72	40	57.14	100	28	64	40
42.23	86	28	44	32	48.61	100	24	56	48	57.30	100	24	44	32
42.66	100	28	86	72	48.61	100	24	28	24	57.33	86	24	64	40
42.78	56	24	44	24	48.86	100	40	86	44	58.33	100	24	56	40
42.86	100	28	48	40	48.89	64	24	44	24	58.44	100	28	72	44
42.86	72	24	40	28	49.11	100	28	44	32	58.64	86	24	72	44
43.00	86	32	64	40	49.14	86	28	64	40	59.53	100	24	40	28
43.00	86	28	56	40	49.27	86	24	44	32	59.72	86	24	40	24
43.00	86	24	48	40	49.77	100	24	86	72	60.00	72	24	64	32
43.64	72	24	64	44	50.00	100	28	56	40	60.00	72	24	56	28
43.75	100	32	56	40	50.00	100	24	48	40	60.00	72	24	48	24
43.98	86	32	72	44	50.00	72	24	40	24	60.61	100	24	64	44
44.44	64	24	40	24	50.00	100	32	64	40	61.08	100	32	86	44
44.64	100	28	40	32	50.17	86	24	56	40	61.43	86	28	64	32
44.68	86	28	64	44	50.26	86	28	72	44	61.43	86	24	48	28
44.79	100	40	86	48	51.14	100	32	72	44	62.22	64	24	56	24
44.79	86	24	40	32	51.19	86	24	40	28	62.50	100	24	72	48
45.00	72	28	56	32	51.43	72	28	64	32	62.50	100	28	56	32
45.00	72	24	48	32	51.43	72	24	48	28	62.50	100	24	48	32
45.45	100	32	64	44	51.95	100	28	64	44	62.71	86	24	56	32
45.45	100	24	48	44	52.08	100	24	40	32	63.99	100	28	86	48
45.46	100	28	56	44	52.12	86	24	64	44	63.99	100	24	86	56
45.61	86	24	56	44	52.50	72	24	56	32	64.29	100	28	72	40
45.72	64	24	48	28	53.03	100	24	56	44	64.50	86	24	72	40
45.84	100	24	44	40	53.33	64	24	56	28	65.48	100	24	44	28
45.92	100	28	72	56	53.33	64	24	48	24	65.70	86	24	44	24
46.07	86	28	72	48	53.57	100	28	72	48	66.67	100	24	64	40
46.07	86	24	72	56	53.57	100	24	72	56	67.19	100	32	86	40
46.07	86	28	48	32						68.18	100	24	72	44
46.67	64	24	56	32	53.57	100	28	48	32	68.57	72	24	64	28
46.67	56	24	48	24	53.75	86	24	72	48	69.11	86	28	72	32
46.88	100	32	72	48	53.75	86	24	48	32	69.44	100	24	40	24
46.88	100	24	72	64	53.75	86	28	56	32	69.80	100	28	86	44
47.15	72	24	44	28	54.85	100	28	86	56	70.00	72	24	56	24
47.62	100	28	64	48	55.00	72	24	44	24	71.43	100	28	64	32
47.62	100	24	64	56	55.28	86	28	72	40	71.43	100	24	48	28
47.62	100	24	32	28	55.56	100	24	32	24	71.67	86	24	64	32
47.78	86	24	64	48	55.56	100	24	64	48	71.67	86	24	56	28
47.78	86	24	32	24	55.99	100	24	86	64	71.67	86	24	48	24
47.99	100	32	86	56	55.99	100	32	86	48	72.92	100	24	56	32
47.99	100	28	86	64	56.25	100	32	72	40	74.65	100	24	86	48

TABLES OF LEADS FOR CAM LOBES

Obtained with Spiral Head and a Vertical Spindle Milling Attachment Set at an Angle

The method of using the Spiral Head and a Vertical Spindle Milling Attachment for cutting the lobes of cams is described in Chapter IX, and the following tables have been worked out to enable the machine to be set up without the necessity of figuring the leads and settings.

In compiling these tables, we have employed the same combinations of change gears as those in the "Table of Approximate Angles for Cutting Spirals," all of which will reach without interfering. The practical leads obtainable with each set of change gears have been grouped together so that when a machine is set for any lead, and it is desired to change to another lead, the operator can quickly determine whether the required lead is available without changing the gears already on. As this is often the case in this work, the saving in time that is effected is readily appreciated.

A selection of cam leads from 0 to 20" is listed, and it should be understood that these are the leads or amount of rise in a complete circle, not the amount of rise of a lobe in a fractional part of the circumference. From the amount of rise of the lobe it will be necessary before using these tables to calculate the lead or rise if the lobe were continued the full circumference. This is easily found as explained on page 179.

In using these tables to set up a machine to mill any required lead, the column under the heading "Approximate Lead" is first followed down until the range of leads is found which embraces the required one. Then follow the horizontal line across until the nearest dimension to the exact lead required is found. At the top of the column containing this dimension will be found the required combination of change gears, and in the next two columns at the right, and in line with the dimension selected, will be found the angles at which to set the spiral head and vertical milling attachment.

Example: Required, the change gears and angles at which to set the spiral head and vertical milling attachment to cut a cam with a lead of .1476".

Following down the first column we find .145-50, which embraces the required lead. Following this line across horizontally we find .1474", which is sufficiently near to .1476" for all practical purposes. At the top of the column containing .1474" is the proper combination of change gears, 24, 86, 32, and 100, and in the two columns at the right and in line with .1474" are the necessary angles; $9\frac{1}{2}^{\circ}$ for spiral head, and $80\frac{1}{2}^{\circ}$ for vertical milling attachment.

When the machine is already set for a given lead and it is desired to know whether another required lead can be obtained without changing the gears, proceed as follows:

Example: Machine is set with a combination of gears, 24, 72, 32, and 86, and a lead of .1080" is required.

Follow down the column of exact leads that are given under the combination of change gears for which the machine is set until .1081" is found. This is sufficiently near to .1080" for all practical purposes. Hence it is possible to obtain this lead without changing the gears, by setting the spiral head at 5° and the vertical milling attachment at 85° .

In milling cams in this way an angle of greater than 80° with the spiral head, which is the greatest angle listed in these tables, should be avoided to prevent going beyond the range of the spiral head.

A vertical spindle milling attachment with offset spindle, as shown on page 77, is preferable for this work, as it will reach nearer to the spiral head spindle when milling small cams with the head set nearly vertical.

We also manufacture an extension by the use of which the spiral head can be moved farther in on the table to bring the spiral head and vertical spindle attachment spindles nearer together. This extension is furnished on special order.

The standard end mill is of sufficient length for practically all leads on ordinary screw machine cams, for long leads usually extend over only a partial turn of the cam.

The mill should be of the same diameter as the roll to be used with the cam, and, in laying out cam, work from the centre of the roll.

The change gears that are furnished with Universal Milling Machines have the following numbers of teeth: 24 (2 gears), 28, 32, 44, 48, 56, 86 and 100.

[illegible]

LEADS FROM .450 TO .600

[illegible]

LEADS FROM .600 TO .750

APPROXIMATE LEAD	GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM			
	24	32	40	100	24	32	40	100	24	32	40	100	24	32	40	100	24	32	40	100	24	32	40	100	24	32	40	100	24	32	40	100
.600-05	42	47	51	56	33	34	35	36	29	29	30	31	26	27	28	29	22	23	24	25	18	19	20	21	14	15	16	17	10	11	12	13
.605-10	43	48	52	57	34	35	36	37	30	30	31	32	27	28	29	30	23	24	25	26	19	20	21	22	15	16	17	18	11	12	13	14
.610-15	44	49	53	58	35	36	37	38	31	31	32	33	28	29	30	31	24	25	26	27	20	21	22	23	16	17	18	19	12	13	14	15
.615-20	45	50	54	59	36	37	38	39	32	32	33	34	29	30	31	32	25	26	27	28	21	22	23	24	17	18	19	20	13	14	15	16
.620-25	46	51	55	60	37	38	39	40	33	33	34	35	30	31	32	33	26	27	28	29	22	23	24	25	18	19	20	21	14	15	16	17
.625-30	47	52	56	61	38	39	40	41	34	34	35	36	31	32	33	34	27	28	29	30	23	24	25	26	19	20	21	22	15	16	17	18
.630-35	48	53	57	62	39	40	41	42	35	35	36	37	32	33	34	35	28	29	30	31	24	25	26	27	20	21	22	23	16	17	18	19
.635-40	49	54	58	63	40	41	42	43	36	36	37	38	33	34	35	36	29	30	31	32	25	26	27	28	21	22	23	24	17	18	19	20
.640-45	50	55	59	64	41	42	43	44	37	37	38	39	34	35	36	37	30	31	32	33	26	27	28	29	22	23	24	25	18	19	20	21
.645-50	51	56	60	65	42	43	44	45	38	38	39	40	35	36	37	38	31	32	33	34	27	28	29	30	23	24	25	26	19	20	21	22
.650-55	52	57	61	66	43	44	45	46	39	39	40	41	36	37	38	39	32	33	34	35	28	29	30	31	24	25	26	27	20	21	22	23
.655-60	53	58	62	67	44	45	46	47	40	40	41	42	37	38	39	40	33	34	35	36	29	30	31	32	25	26	27	28	21	22	23	24
.660-65	54	59	63	68	45	46	47	48	41	41	42	43	38	39	40	41	34	35	36	37	30	31	32	33	26	27	28	29	22	23	24	25
.665-70	55	60	64	69	46	47	48	49	42	42	43	44	39	40	41	42	35	36	37	38	31	32	33	34	27	28	29	30	23	24	25	26
.670-75	56	61	65	70	47	48	49	50	43	43	44	45	40	41	42	43	36	37	38	39	32	33	34	35	28	29	30	31	24	25	26	27
.675-80	57	62	66	71	48	49	50	51	44	44	45	46	41	42	43	44	37	38	39	40	33	34	35	36	29	30	31	32	25	26	27	28
.680-85	58	63	67	72	49	50	51	52	45	45	46	47	42	43	44	45	38	39	40	41	34	35	36	37	30	31	32	33	26	27	28	29
.685-90	59	64	68	73	50	51	52	53	46	46	47	48	43	44	45	46	39	40	41	42	35	36	37	38	31	32	33	34	27	28	29	30
.690-95	60	65	69	74	51	52	53	54	47	47	48	49	44	45	46	47	40	41	42	43	36	37	38	39	32	33	34	35	28	29	30	31
.695-00	61	66	70	75	52	53	54	55	48	48	49	50	45	46	47	48	41	42	43	44	37	38	39	40	33	34	35	36	29	30	31	32
.700-05	62	67	71	76	53	54	55	56	49	49	50	51	46	47	48	49	42	43	44	45	38	39	40	41	34	35	36	37	30	31	32	33
.705-10	63	68	72	77	54	55	56	57	50	50	51	52	47	48	49	50	43	44	45	46	39	40	41	42	35	36	37	38	31	32	33	34
.710-15	64	69	73	78	55	56	57	58	51	51	52	53	48	49	50	51	44	45	46	47	40	41	42	43	36	37	38	39	32	33	34	35
.715-20	65	70	74	79	56	57	58	59	52	52	53	54	49	50	51	52	45	46	47	48	41	42	43	44	37	38	39	40	33	34	35	36
.720-25	66	71	75	80	57	58	59	60	53	53	54	55	50	51	52	53	46	47	48	49	42	43	44	45	38	39	40	41	34	35	36	37
.725-30	67	72	76	81	58	59	60	61	54	54	55	56	51	52	53	54	47	48	49	50	43	44	45	46	39	40	41	42	35	36	37	38
.730-35	68	73	77	82	59	60	61	62	55	55	56	57	52	53	54	55	48	49	50	51	44	45	46	47	40	41	42	43	36	37	38	39
.735-40	69	74	78	83	60	61	62	63	56	56	57	58	53	54	55	56	49	50	51	52	45	46	47	48	41	42	43	44	37	38	39	40
.740-45	70	75	79	84	61	62	63	64	57	57	58	59	54	55	56	57	50	51	52	53	46	47	48	49	42	43	44	45	38	39	40	41
.745-50	71	76	80	85	62	63	64	65	58	58	59	60	55	56	57	58	51	52	53	54	47	48	49	50	43	44	45	46	39	40	41	42

LEADS FROM .900 TO 1.050

APPROXIMATE LEAD	GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM			
---------------------	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--

LEADS FROM 1.050 TO 1.200

LEAD	APPROXIMATE											
	24	32	40	48	56	64	72	80	88	96	100	DEGREES
1.050-55	1.0518	58	32	1.0508	52	38	1.0513	44	45	1.0549	41	48
1.055-60	1.0532	58	31	1.0577	52	37	1.0559	44	45	1.0558	38	52
1.060-65	1.0632	59	31	1.0613	52	37	1.0606	45	45	1.0617	38	51
1.065-70	1.0657	59	30	1.0650	53	37	1.0698	45	44	1.0674	38	51
1.070-75	1.0740	60	30	1.0720	53	36	1.0744	45	44	1.0732	39	51
1.075-80	1.0795	60	29	1.0788	54	36	1.0790	46	44	1.0758	42	47
1.080-85	1.0848	61	29	1.0822	54	35	1.0835	46	43	1.0809	42	47
1.085-90	1.0871	61	28	1.0856	54	35	1.0879	46	43	1.0861	42	47
1.090-95	1.0900	61	28	1.0923	55	35	1.0924	46	43	1.0911	43	47
1.095-00	1.0950	62	28	1.0950	55	34	1.0958	47	43	1.0963	43	46
1.100-05	1.1000	62	27	1.1022	55	34	1.1014	47	42	1.1014	43	46
1.105-10	1.1050	63	27	1.1055	56	34	1.1058	47	42	1.1063	43	46
1.110-15	1.1148	64	26	1.1119	56	33	1.1148	48	42	1.1115	44	46
1.115-20	1.1195	64	25	1.1184	57	33	1.1180	48	41	1.1163	44	45
1.120-25	1.1240	65	25	1.1247	57	32	1.1234	48	41	1.1213	44	45
1.125-30	1.1286	65	24	1.1278	57	32	1.1277	48	41	1.1262	44	45
1.130-35	1.1335	66	24	1.1308	58	32	1.1320	49	41	1.1313	45	45
1.135-40	1.1375	66	23	1.1369	58	31	1.1363	49	40	1.1362	45	44
1.140-45	1.1417	67	23	1.1430	59	31	1.1405	49	40	1.1411	45	44
1.145-50	1.1459	67	22	1.1489	59	30	1.1490	50	40	1.1460	45	44
1.150-55	1.1500	68	22	1.1548	60	30	1.1532	50	39	1.1508	46	44
1.155-60	1.1598	69	20	1.1578	60	29	1.1573	50	39	1.1557	46	43
1.160-65	1.1618	69	20	1.1606	60	29	1.1615	50	39	1.1606	46	43
1.165-70	1.1655	70	19	1.1662	61	29	1.1656	51	39	1.1654	46	43
1.170-75	1.1721	71	19	1.1718	61	28	1.1738	51	38	1.1700	47	43
1.175-80	1.1767	71	18	1.1775	62	28	1.1778	51	38	1.1795	47	42
1.180-85	1.1829	72	17	1.1828	62	27	1.1819	52	38	1.1841	47	42
1.185-90	1.1860	73	17	1.1881	63	27	1.1861	52	37	1.1891	48	42
1.190-95	1.1922	74	16	1.1934	63	26	1.1900	52	37	1.1935	48	41
1.195-00	1.1980	75	15	1.1986	64	26	1.1980	53	37	1.1981	48	41
1.200-05	1.2028	76	15	1.2034	65	26	1.2024	54	37	1.2025	49	41
1.205-10	1.2074	77	15	1.2080	66	26	1.2070	54	36	1.2070	49	41
1.210-15	1.2120	78	15	1.2126	67	26	1.2116	55	36	1.2116	50	41
1.215-20	1.2166	79</										

LEADS FROM 1.350 TO 1.500

LEAD APPROXIMATE	GEAR ON WORM												GEAR ON SCREW												VERTICAL ATT.											
	28	32	36	40	45	50	55	DEGREES	ANGLE TO SET	SPIRAL HEAD	ANGLE TO SET	GEAR ON SCREW	1ST ON STUD	2ND ON STUD	100	ANGLE TO SET	SPIRAL HEAD	ANGLE TO SET	GEAR ON SCREW	1ST ON STUD	2ND ON STUD	100	ANGLE TO SET	SPIRAL HEAD	ANGLE TO SET	GEAR ON SCREW	1ST ON STUD	2ND ON STUD	100							
1.350-55	1.3530	57° 32'	1.3530	52° 37'	1.3533	48° 41'	1.3512	44° 45'	1.3511	38° 51'	1.3550	36° 53'	1.3550	36° 53'	1.3522	33° 56'	1.3511	38° 51'	1.3550	36° 53'	1.3550	36° 53'	1.3522	33° 56'	1.3511	38° 51'	1.3550	36° 53'	1.3550	36° 53'						
1.355-60	1.3570	58° 32'	1.3570	53° 37'	1.3583	49° 41'	1.3576	45° 45'	1.3575	39° 51'	1.3617	42° 48'	1.3617	42° 48'	1.3611	33° 56'	1.3575	39° 51'	1.3617	42° 48'	1.3617	42° 48'	1.3611	33° 56'	1.3575	39° 51'	1.3617	42° 48'	1.3617	42° 48'						
1.360-65	1.3641	58° 31'	1.3620	53° 37'	1.3635	49° 40'	1.3633	45° 44'	1.3632	39° 51'	1.3682	42° 47'	1.3682	42° 47'	1.3659	34° 56'	1.3632	39° 51'	1.3682	42° 47'	1.3682	42° 47'	1.3659	34° 56'	1.3632	39° 51'	1.3682	42° 47'	1.3682	42° 47'						
1.365-70	1.3676	58° 31'	1.3665	53° 36'	1.3686	49° 40'	1.3693	45° 44'	1.3693	39° 50'	1.3748	42° 47'	1.3748	42° 47'	1.3700	34° 56'	1.3693	39° 50'	1.3748	42° 47'	1.3748	42° 47'	1.3700	34° 56'	1.3693	39° 50'	1.3748	42° 47'	1.3748	42° 47'						
1.370-75	1.3713	59° 31'	1.3710	53° 36'	1.3738	49° 40'	1.3751	45° 44'	1.3751	39° 50'	1.3815	42° 47'	1.3815	42° 47'	1.3789	34° 55'	1.3751	39° 50'	1.3815	42° 47'	1.3815	42° 47'	1.3789	34° 55'	1.3751	39° 50'	1.3815	42° 47'	1.3815	42° 47'						
1.375-80	1.3784	59° 30'	1.3768	54° 36'	1.3788	50° 40'	1.3810	46° 44'	1.3810	40° 49'	1.3878	43° 47'	1.3878	43° 47'	1.3877	34° 55'	1.3768	54° 36'	1.3810	46° 44'	1.3878	43° 47'	1.3877	34° 55'	1.3768	54° 36'	1.3810	46° 44'	1.3878	43° 47'						
1.380-85	1.3819	59° 30'	1.3840	54° 35'	1.3838	50° 39'	1.3868	46° 43'	1.3868	40° 48'	1.3925	46° 43'	1.3925	46° 43'	1.3904	34° 55'	1.3838	50° 39'	1.3868	46° 43'	1.3925	46° 43'	1.3904	34° 55'	1.3838	50° 39'	1.3868	46° 43'	1.3925	46° 43'						
1.385-90	1.3855	60° 30'	1.3883	54° 33'	1.3868	50° 39'	1.3925	46° 43'	1.3925	40° 48'	1.4005	43° 46'	1.4005	43° 46'	1.4052	35° 55'	1.3855	60° 30'	1.3883	54° 33'	1.3868	50° 39'	1.3925	46° 43'	1.4005	43° 46'	1.4005	43° 46'	1.4052	35° 55'						
1.390-95	1.3925	60° 29'	1.3927	54° 35'	1.3938	50° 39'	1.3985	50° 39'	1.3985	40° 48'	1.4135	44° 46'	1.4135	44° 46'	1.4140	35° 54'	1.3925	60° 29'	1.3927	54° 35'	1.3938	50° 39'	1.3985	50° 39'	1.3985	40° 48'	1.4135	44° 46'	1.4135	44° 46'						
1.395-00	1.3992	61° 29'	1.3970	55° 35'	1.3987	51° 39'	1.3983	46° 43'	1.3983	40° 48'	1.4155	47° 42'	1.4155	47° 42'	1.4227	35° 54'	1.3970	55° 35'	1.3987	51° 39'	1.3983	46° 43'	1.3983	40° 48'	1.4155	47° 42'	1.4155	47° 42'	1.4227	35° 54'						
1.400-05	1.4025	61° 28'	1.4012	55° 34'	1.4036	51° 38'	1.4040	47° 43'	1.4040	40° 49'	1.4071	43° 46'	1.4071	43° 46'	1.4265	38° 51'	1.4012	55° 34'	1.4036	51° 38'	1.4040	47° 43'	1.4040	40° 49'	1.4071	43° 46'	1.4071	43° 46'	1.4265	38° 51'						
1.405-10	1.4059	61° 28'	1.4055	55° 34'	1.4085	51° 38'	1.4098	47° 42'	1.4098	40° 49'	1.4262	44° 45'	1.4262	44° 45'	1.4313	35° 54'	1.4055	55° 34'	1.4085	51° 38'	1.4098	47° 42'	1.4098	40° 49'	1.4262	44° 45'	1.4262	44° 45'	1.4313	35° 54'						
1.410-15	1.4128	62° 28'	1.4139	56° 34'	1.4134	51° 38'	1.4155	47° 42'	1.4155	40° 49'	1.4326	44° 45'	1.4326	44° 45'	1.4400	36° 54'	1.4128	62° 28'	1.4139	56° 34'	1.4134	51° 38'	1.4155	47° 42'	1.4155	40° 49'	1.4326	44° 45'	1.4326	44° 45'						
1.415-20	1.4190	62° 27'	1.4180	56° 33'	1.4182	52° 38'	1.4212	47° 42'	1.4212	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'	1.4180	56° 33'	1.4182	52° 38'	1.4212	47° 42'	1.4212	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'						
1.420-25	1.4223	62° 27'	1.4220	56° 33'	1.4233	52° 37'	1.4267	48° 42'	1.4267	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'	1.4220	56° 33'	1.4233	52° 37'	1.4267	48° 42'	1.4267	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'						
1.425-30	1.4254	63° 27'	1.4267	56° 33'	1.4280	52° 37'	1.4267	48° 42'	1.4267	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'	1.4254	63° 27'	1.4267	56° 33'	1.4280	52° 37'	1.4267	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'						
1.430-35	1.4318	63° 26'	1.4304	57° 33'	1.4328	52° 37'	1.4322	48° 41'	1.4322	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'	1.4318	63° 26'	1.4304	57° 33'	1.4328	52° 37'	1.4322	48° 41'	1.4322	40° 49'	1.4389	45° 45'	1.4389	45° 45'						
1.435-40	1.4380	64° 26'	1.4385	57° 33'	1.4375	52° 37'	1.4379	48° 41'	1.4379	40° 49'	1.4389	45° 45'	1.4389	45° 45'	1.4451	37° 53'	1.4380	64° 26'	1.4385	57° 33'	1.4375	52° 37'	1.4379	48° 41'	1.4379	40° 49'	1.4389	45° 45'	1.4389	45° 45'						
1.440-45	1.4441	64° 25'	1.4423	57° 33'	1.4422	53° 36'	1.4435	49° 41'	1.4435	40° 49'	1.4451	37° 53'	1.4451	37° 53'	1.4451	37° 53'	1.4441	64° 25'	1.4423	57° 33'	1.4422	53° 36'	1.4435	49° 41'	1.4435	40° 49'	1.4451	37° 53'	1.4451	37° 53'						
1.445-50	1.4499	65° 25'	1.4462	58° 32'	1.4469	53° 36'	1.4490	49° 41'	1.4490	40° 49'	1.4451	37° 53'	1.4451	37° 53'	1.4451	37° 53'	1.4499	65° 25'	1.4462	58° 32'	1.4469	53° 36'	1.4490	49° 41'	1.4490	40° 49'	1.4451	37° 53'	1.4451	37° 53'						
1.450-55	1.4529	65° 24'	1.4540	58° 31'	1.4515	53° 36'	1.4544	49° 40'	1.4544	40° 49'	1.4515	37° 53'	1.4515	37° 53'	1.4515	37° 53'	1.4529	65° 24'	1.4540	58° 31'	1.4515	53° 36'	1.4544	49° 40'	1.4544	40° 49'	1.4515	37° 53'	1.4515	37° 53'						
1.455-60	1.4558	65° 24'	1.4579	58° 31'	1.4561	54° 36'	1.4590	49° 40'	1.4590	40° 49'	1.4561	54° 36'	1.4561	54° 36'	1.4561	54° 36'	1.4558	65° 24'	1.4579	58° 31'	1.4561	54° 36'	1.4590	49° 40'	1.4590	40° 49'	1.4561	54° 36'	1.4561	54° 36'						
1.460-65	1.4617	66° 24'	1.4619	59° 31'	1.4607	54° 35'	1.4637	46° 44'	1.4637	46° 44'	1.4607	54° 35'	1.4607	54° 35'	1.4607	54° 35'	1.4617	66° 24'	1.4619	59° 31'	1.4607	54° 35'	1.4637	46° 44'	1.4637	46° 44'	1.4607	54° 35'	1.4607	54° 35'						
1.465-70	1.4672	66° 23'	1.4693	59° 30'	1.4652	54° 35'	1.4699	46° 43'	1.4699	46° 43'	1.4652	54° 35'	1.4652	54° 35'	1.4652	54° 35'	1.4672	66° 23'	1.4693	59° 30'	1.4652	54° 35'	1.4699	46° 43'	1.4699	46° 43'	1.4652	54° 35'	1.4652	54° 35'						
1.470-75	1.4726	67° 23'	1.4731	59° 30'	1.4745	55° 34'	1.4769	50° 40'	1.4769	50° 40'	1.4745	55° 34'	1.4745	55° 34'	1.4745	55° 34'	1.4726	67° 23'	1.4731	59° 30'	1.4745	55° 34'	1.4769	50° 40'	1.4769	50° 40'	1.4745	55° 34'	1.4745	55° 34'						
1.475-80	1.4780	67° 22'	1.4769	60° 30'	1.4789	55° 35'	1.4769	50° 40'	1.4769	50° 40'	1.4789	55° 35'	1.4789	55° 35'	1.4789	55° 35'	1.4780	67° 22'	1.4769	60° 30'	1.4789	55° 35'	1.4769	50° 40'	1.4769	50° 40'	1.4789	55° 35'	1.4789	55° 35'						
1.480-85	1.4835	68° 22'	1.4844	60° 29'	1.4833	55° 34'	1.4813	50° 39'	1.4813	50° 39'	1.4833	55° 34'	1.4833	55° 34'	1.4833	55° 34'	1.4835	68° 22'	1.4844	60° 29'	1.4833	55° 34'	1.4813	50° 39'	1.4813	50° 39'	1.4833	55° 34'	1.4833	55° 34'						
1.485-90	1.4885	68° 21'	1.4879	60° 29'	1.4875	55° 34'	1.4867	50° 39'	1.4867	50° 39'	1.4875	55° 34'	1.4875	55° 34'	1.4875	55° 34'	1.4885	68° 21'	1.4879	60° 29'	1.4875	55° 34'	1.4867	50° 39'	1.4867	50° 39'	1.4875	55° 34'	1.4875	55° 34'						
1.490-95	1.4938	69° 21'	1.4916	61° 29'	1.4921	56° 34'	1.4919	51° 39'	1.4919	51° 39'	1.4921	56° 34'	1.4921	56° 34'	1.4921	56° 34'	1.4938	69° 21'	1.4916	61° 29'	1.4921	56° 34'	1.4919	51° 39'	1.4919	51° 39'	1.4921	56° 34'	1.4921	56° 34'						
1.495-00	1.4988	69° 20'	1.4987	61° 28'	1.4964	56° 33'	1.4972	51° 38'	1.4972	51° 38'	1.4964	56° 33'	1.4964	56° 33'	1.4964	56° 33'	1.4988	69° 20'	1.4987	61° 28'	1.4964	56° 33'	1.4972	51° 38'	1.4972	51° 38'	1.4964	56° 33'	1.4964	56° 33'						

LEADS FROM 1.650 TO 1.800

APPROXIMATE LEAD	24	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720	740	760	780	800	820	840	860	880	900	920	940	960	980	1000	1020	1040	1060	1080	1100	1120	1140	1160	1180	1200	1220	1240	1260	1280	1300	1320	1340	1360	1380	1400	1420	1440	1460	1480	1500	1520	1540	1560	1580	1600	1620	1640	1660	1680	1700	1720	1740	1760	1780	1800																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
1.650-55	1.6541	59	30	1.6514	54	35	1.6537	49	40	1.6560	54	35	1.6583	61	29	1.6606	55	35	1.6629	60	29	1.6652	60	29	1.6675	60	29	1.6698	61	29	1.6721	61	29	1.6744	61	29	1.6767	61	29	1.6790	61	29	1.6813	61	29	1.6836	61	29	1.6859	61	29	1.6882	61	29	1.6905	61	29	1.6928	61	29	1.6951	61	29	1.6974	61	29	1.6997	61	29	1.7020	61	29	1.7043	61	29	1.7066	61	29	1.7089	61	29	1.7112	61	29	1.7135	61	29	1.7158	61	29	1.7181	61	29	1.7204	61	29	1.7227	61	29	1.7250	61	29	1.7273	61	29	1.7296	61	29	1.7319	61	29	1.7342	61	29	1.7365	61	29	1.7388	61	29	1.7411	61	29	1.7434	61	29	1.7457	61	29	1.7480	61	29	1.7503	61	29	1.7526	61	29	1.7549	61	29	1.7572	61	29	1.7595	61	29	1.7618	61	29	1.7641	61	29	1.7664	61	29	1.7687	61	29	1.7710	61	29	1.7733	61	29	1.7756	61	29	1.7779	61	29	1.7802	61	29	1.7825	61	29	1.7848	61	29	1.7871	61	29	1.7894	61	29	1.7917	61	29	1.7940	61	29	1.7963	61	29	1.7986	61	29	1.8009	61	29	1.8032	61	29	1.8055	61	29	1.8078	61	29	1.8101	61	29	1.8124	61	29	1.8147	61	29	1.8170	61	29	1.8193	61	29	1.8216	61	29	1.8239	61	29	1.8262	61	29	1.8285	61	29	1.8308	61	29	1.8331	61	29	1.8354	61	29	1.8377	61	29	1.8400	61	29	1.8423	61	29	1.8446	61	29	1.8469	61	29	1.8492	61	29	1.8515	61	29	1.8538	61	29	1.8561	61	29	1.8584	61	29	1.8607	61	29	1.8630	61	29	1.8653	61	29	1.8676	61	29	1.8699	61	29	1.8722	61	29	1.8745	61	29	1.8768	61	29	1.8791	61	29	1.8814	61	29	1.8837	61	29	1.8860	61	29	1.8883	61	29	1.8906	61	29	1.8929	61	29	1.8952	61	29	1.8975	61	29	1.8998	61	29	1.9021	61	29	1.9044	61	29	1.9067	61	29	1.9090	61	29	1.9113	61	29	1.9136	61	29	1.9159	61	29	1.9182	61	29	1.9205	61	29	1.9228	61	29	1.9251	61	29	1.9274	61	29	1.9297	61	29	1.9320	61	29	1.9343	61	29	1.9366	61	29	1.9389	61	29	1.9412	61	29	1.9435	61	29	1.9458	61	29	1.9481	61	29	1.9504	61	29	1.9527	61	29	1.9550	61	29	1.9573	61	29	1.9596	61	29	1.9619	61	29	1.9642	61	29	1.9665	61	29	1.9688	61	29	1.9711	61	29	1.9734	61	29	1.9757	61	29	1.9780	61	29	1.9803	61	29	1.9826	61	29	1.9849	61	29	1.9872	61	29	1.9895	61	29	1.9918	61	29	1.9941	61	29	1.9964	61	29	1.9987	61	29	2.0010	61	29	2.0033	61	29	2.0056	61	29	2.0079	61	29	2.0102	61	29	2.0125	61	29	2.0148	61	29	2.0171	61	29	2.0194	61	29	2.0217	61	29	2.0240	61	29	2.0263	61	29	2.0286	61	29	2.0309	61	29	2.0332	61	29	2.0355	61	29	2.0378	61	29	2.0401	61	29	2.0424	61	29	2.0447	61	29	2.0470	61	29	2.0493	61	29	2.0516	61	29	2.0539	61	29	2.0562	61	29	2.0585	61	29	2.0608	61	29	2.0631	61	29	2.0654	61	29	2.0677	61	29	2.0700	61	29	2.0723	61	29	2.0746	61	29	2.0769	61	29	2.0792	61	29	2.0815	61	29	2.0838	61	29	2.0861	61	29	2.0884	61	29	2.0907	61	29	2.0930	61	29	2.0953	61	29	2.0976	61	29	2.0999	61	29	2.1022	61	29	2.1045	61	29	2.1068	61	29	2.1091	61	29	2.1114	61	29	2.1137	61	29	2.1160	61	29	2.1183	61	29	2.1206	61	29	2.1229	61	29	2.1252	61	29	2.1275	61	29	2.1298	61	29	2.1321	61	29	2.1344	61	29	2.1367	61	29	2.1390	61	29	2.1413	61	29	2.1436	61	29	2.1459	61	29	2.1482	61	29	2.1505	61	29	2.1528	61	29	2.1551	61	29	2.1574	61	29	2.1597	61	29	2.1620	61	29	2.1643	61	29	2.1666	61	29	2.1689	61	29	2.1712	61	29	2.1735	61	29	2.1758	61	29	2.1781	61	29	2.1804	61	29	2.1827	61	29	2.1850	61	29	2.1873	61	29	2.1896	61	29	2.1919	61	29	2.1942	61	29	2.1965	61	29	2.1988	61	29	2.2011	61	29	2.2034	61	29	2.2057	61	29	2.2080	61	29	2.2103	61	29	2.2126	61	29	2.2149	61	29	2.2172	61	29	2.2195	61	29	2.2218	61	29	2.2241	61	29	2.2264	61	29	2.2287	61	29	2.2310	61	29	2.2333	61	29	2.2356	61	29	2.2379	61	29	2.2402	61	29	2.2425	61	29	2.2448	61	29	2.2471	61	29	2.2494	61	29	2.2517	61	29	2.2540	61	29	2.2563	61	29	2.2586	61	29	2.2609	61	29	2.2632	61	29	2.2655	61	29	2.2678	61	29	2.2701	61	29	2.2724	61	29	2.2747	61	29	2.2770	61	29	2.2793	61	29	2.2816	61	29	2.2839	61	29	2.2862	61	29	2.2885	61	29	2.2908	61	29	2.2931	61	29	2.2954	61	29	2.2977	61	29	2.3000	61	29	2.3023	61	29	2.3046	61	29	2.3069	61	29	2.3092	61	29	2.3115	61	29	2.3138	61	29	2.3161	61	29	2.3184	61	29	2.3207	61	29	2.3230	61	29	2.3253	61	29	2.3276	61	29	2.3299	61	29	2.3322	61	29	2.3345	61	29	2.3368	61	29	2.3391	61	29	2.3414	61	29	2.3437	61	29	2.3460	61	29	2.3483	61	29	2.3506	61	29	2.3529	61	29	2.3552	61	29	2.3575	61	29	2.3598	61	29	2.3621	61	29	2.3644	61	29	2.3667	61	29	2.3690	61	29	2.3713	61	29	2.3736	61	29	2.3759	61	29	2.3782	61	29	2.3805	61	29	2.3828	61	29	2.3851	61	29	2.3874	61	29	2.3897	61	29	2.3920	61	29	2.3943	61	29	2.3966	61	29	2.3989	61	29	2.4012	61	29	2.4035	61	29	2.4058	61	29	2.4081	61	29	2.4104	61	29	2.4127	61	29	2.4150	61	29	2.4173	61	29	2.4196	61	29	2.4219	61	29	2.4242	61	29	2.4265	61	29	2.4288	61	29	2.4311	61	29	2.4334	61	29	2.4357	61	29	2.4380	61	29	2.4403	61	29	2.4426	61	29	2.4449	61	29	2.4472	61	29	2.4495	61	29	2.4518	61	29	2.4541	61	29	2.4564	61	29	2.4587	61	29	2.4610	61	29	2.4633	61	29	2.4656	61	29	2.4679	61	29	2.4702	61	29	2.4725	61	29	2.4748	61	29	2.4771	61	29	2.4794	61	29	2.4817	61	29	2.4840	61	29	2.4863	61	29	2.4886	61	29	2.4909	61	29	2.4932	61	29	2.4955	61	29	2.4978	61	29	2.5001	61	29	2.5024	61	29	2.5047	61	29	2.5070	61	29	2.5093	61	29	2.5116	61	29	2.5139	61	29	2.5162	61	29	2.5185	61	29	2.5208	61	29	2.5231	61	29	2.5254	61	29	2.5277	61	29	2.5300	61	29	2.5323	61	29	2.5346	61	29	2.5369	61	29	2.5392	61	29	2.5415	61	29	2.5438	61	29	2.5461	61	29	2.5484	61	29	2.5507	61	29	2.5530	61	29	2.5553	61	29	2.5576	61	29	2.5599	61	29	2.5622	61	29	2.5645	61	29	2.5668	61	29	2.5691	61	29	2.5714	61	29	2.5737	61	29	2.5760	61	29	2.5783	61	29	2.5806	61	29	2.5829	61	29	2.5852	61	29	2.5875	61	29	2.5898	61	29	2.5921	61	29	2.5944	61	29	2.5967	61	29	2.5990	61	29	2.6013	61	29	2.6036	61	29	2.6059	61	29	2.6082	61	29	2.6105	61	29	2.6128	61	29	2.6151	61	29	2.6174	61	29	2.6197	61	29	2.6220	61	29	2.6243	61	29	2.6266	61	29	2.6289	61	29	2.6312	61	29	2.6335	61	29	2.6358	61	29	2.6381	61	29	2.6404	61	29	2.6427	61	29	2.6450	61	29	2.6473	61	29	2.6496	61	29	2.6519	61	29	2.6542	61	29	2.6565	61	29	2.6588	61	29	2.6611	61	29	2.6634	61	29	2.6657	61	29	2.6680	61	29	2.6703	61	29	2.6726	61	29	2.6749	61	29	2.6772	61	29	2.6795	61	29	2.6818	61	29	2.6841	61	29	2.6864	61	29	2.6887	61	29	2.6910	61	29	2.6933	61	29	2.6956	61	29	2.6979	61	29	2.7002	61

LEADS FROM 1.950 TO 2.100

APPROXIMATE LEAD	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368	370	372	374	376	378	380	382	384	386	388	390	392	394	396	398	400	402	404	406	408	410	412	414	416	418	420	422	424	426	428	430	432	434	436	438	440	442	444	446	448	450	452	454	456	458	460	462	464	466	468	470	472	474	476	478	480	482	484	486	488	490	492	494	496	498	500	502	504	506	508	510	512	514	516	518	520	522	524	526	528	530	532	534	536	538	540	542	544	546	548	550	552	554	556	558	560	562	564	566	568	570	572	574	576	578	580	582	584	586	588	590	592	594	596	598	600	602	604	606	608	610	612	614	616	618	620	622	624	626	628	630	632	634	636	638	640	642	644	646	648	650	652	654	656	658	660	662	664	666	668	670	672	674	676	678	680	682	684	686	688	690	692	694	696	698	700	702	704	706	708	710	712	714	716	718	720	722	724	726	728	730	732	734	736	738	740	742	744	746	748	750	752	754	756	758	760	762	764	766	768	770	772	774	776	778	780	782	784	786	788	790	792	794	796	798	800	802	804	806	808	810	812	814	816	818	820	822	824	826	828	830	832	834	836	838	840	842	844	846	848	850	852	854	856	858	860	862	864	866	868	870	872	874	876	878	880	882	884	886	888	890	892	894	896	898	900	902	904	906	908	910	912	914	916	918	920	922	924	926	928	930	932	934	936	938	940	942	944	946	948	950	952	954	956	958	960	962	964	966	968	970	972	974	976	978	980	982	984	986	988	990	992	994	996	998	1000	1002	1004	1006	1008	1010	1012	1014	1016	1018	1020	1022	1024	1026	1028	1030	1032	1034	1036	1038	1040	1042	1044	1046	1048	1050	1052	1054	1056	1058	1060	1062	1064	1066	1068	1070	1072	1074	1076	1078	1080	1082	1084	1086	1088	1090	1092	1094	1096	1098	1100	1102	1104	1106	1108	1110	1112	1114	1116	1118	1120	1122	1124	1126	1128	1130	1132	1134	1136	1138	1140	1142	1144	1146	1148	1150	1152	1154	1156	1158	1160	1162	1164	1166	1168	1170	1172	1174	1176	1178	1180	1182	1184	1186	1188	1190	1192	1194	1196	1198	1200	1202	1204	1206	1208	1210	1212	1214	1216	1218	1220	1222	1224	1226	1228	1230	1232	1234	1236	1238	1240	1242	1244	1246	1248	1250	1252	1254	1256	1258	1260	1262	1264	1266	1268	1270	1272	1274	1276	1278	1280	1282	1284	1286	1288	1290	1292	1294	1296	1298	1300	1302	1304	1306	1308	1310	1312	1314	1316	1318	1320	1322	1324	1326	1328	1330	1332	1334	1336	1338	1340	1342	1344	1346	1348	1350	1352	1354	1356	1358	1360	1362	1364	1366	1368	1370	1372	1374	1376	1378	1380	1382	1384	1386	1388	1390	1392	1394	1396	1398	1400	1402	1404	1406	1408	1410	1412	1414	1416	1418	1420	1422	1424	1426	1428	1430	1432	1434	1436	1438	1440	1442	1444	1446	1448	1450	1452	1454	1456	1458	1460	1462	1464	1466	1468	1470	1472	1474	1476	1478	1480	1482	1484	1486	1488	1490	1492	1494	1496	1498	1500	1502	1504	1506	1508	1510	1512	1514	1516	1518	1520	1522	1524	1526	1528	1530	1532	1534	1536	1538	1540	1542	1544	1546	1548	1550	1552	1554	1556	1558	1560	1562	1564	1566	1568	1570	1572	1574	1576	1578	1580	1582	1584	1586	1588	1590	1592	1594	1596	1598	1600	1602	1604	1606	1608	1610	1612	1614	1616	1618	1620	1622	1624	1626	1628	1630	1632	1634	1636	1638	1640	1642	1644	1646	1648	1650	1652	1654	1656	1658	1660	1662	1664	1666	1668	1670	1672	1674	1676	1678	1680	1682	1684	1686	1688	1690	1692	1694	1696	1698	1700	1702	1704	1706	1708	1710	1712	1714	1716	1718	1720	1722	1724	1726	1728	1730	1732	1734	1736	1738	1740	1742	1744	1746	1748	1750	1752	1754	1756	1758	1760	1762	1764	1766	1768	1770	1772	1774	1776	1778	1780	1782	1784	1786	1788	1790	1792	1794	1796	1798	1800	1802	1804	1806	1808	1810	1812	1814	1816	1818	1820	1822	1824	1826	1828	1830	1832	1834	1836	1838	1840	1842	1844	1846	1848	1850	1852	1854	1856	1858	1860	1862	1864	1866	1868	1870	1872	1874	1876	1878	1880	1882	1884	1886	1888	1890	1892	1894	1896	1898	1900	1902	1904	1906	1908	1910	1912	1914	1916	1918	1920	1922	1924	1926	1928	1930	1932	1934	1936	1938	1940	1942	1944	1946	1948	1950	1952	1954	1956	1958	1960	1962	1964	1966	1968	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	2026	2028	2030	2032	2034	2036	2038	2040	2042	2044	2046	2048	2050	2052	2054	2056	2058	2060	2062	2064	2066	2068	2070	2072	2074	2076	2078	2080	2082	2084	2086	2088	2090	2092	2094	2096	2098	2100	2102	2104	2106	2108	2110	2112	2114	2116	2118	2120	2122	2124	2126	2128	2130	2132	2134	2136	2138	2140	2142	2144	2146	2148	2150	2152	2154	2156	2158	2160	2162	2164	2166	2168	2170	2172	2174	2176	2178	2180	2182	2184	2186	2188	2190	2192	2194	2196	2198	2200	2202	2204	2206	2208	2210	2212	2214	2216	2218	2220	2222	2224	2226	2228	2230	2232	2234	2236	2238	2240	2242	2244	2246	2248	2250	2252	2254	2256	2258	2260	2262	2264	2266	2268	2270	2272	2274	2276	2278	2280	2282	2284	2286	2288	2290	2292	2294	2296	2298	2300	2302	2304	2306	2308	2310	2312	2314	2316	2318	2320	2322	2324	2326	2328	2330	2332	2334	2336	2338	2340	2342	2344	2346	2348	2350	2352	2354	2356	2358	2360	2362	2364	2366	2368	2370	2372	2374	2376	2378	2380	2382	2384	2386	2388	2390	2392	2394	2396	2398	2400	2402	2404	2406	2408	2410	2412	2414	2416	2418	2420	2422	2424	2426	2428	2430	2432	2434	2436	2438	2440	2442	2444	2446	2448	2450	2452	2454	2456	2458	2460	2462	2464	2466	2468	2470	2472	2474	2476	2478	2480	2482	2484	2486	2488	2490	2492	2494	2496	2498	2500	2502	2504	2506	2508	2510	2512	2514	2516	2518	2520	2522	2524	2526	2528	2530	2532	2534	2536	2538	2540	2542	2544	2546	2548	2550	2552	2554	2556	2558	2560	2562	2564	2566	2568	2570	2572	2574	2576	2578	2580	2582	2584	2586	2588	2590	2592	2594	2596	2598	2600	2602	2604	2606	2608	2610	2612	2614	2616	2618	2620	2622	2624	2626	2628	2630	2632	2634	2636	2638	2640	2642	2644	2646	2648	2650	2652	2654	2656	2658	2660	2662	2664	2666	2668	2670	2672	2674	2676	2678	2680	2682	2684	2686	2688	2690	2692	2694	2696	2698	2700	2702	2704	2706	2708	2710	2712	2714	2716	2718	2720	2722	2724	2726	2728	2730	2732	2734	2736	2738	2740	2742	2744	2746	2748	2750	2752	2754	2756	2758	2760	2762	2764	2766	2768	2770	2772	2774	2776	2778	2780	2782	2784	2786	2788	2790	2792	2794	2796	2798	2800	2802	2804	2806	2808	2810	2812	2814	2816	2818	2820	2822	2824	2826	2828	2830	2832	2834	2836	2838	2840	2842	2844	2846	2848	2850	2852	2854
---------------------	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

LEADS FROM 2.250 TO 2.400

[illegible]

LEADS FROM 2.550 TO 2.700

[illegible]

LEADS FROM 2,850 TO 3,000

[illegible]

LEADS FROM 3.150 TO 3.300

[illegible]

LEADS FROM 3.600 TO 3.900

LEAD APPROXIMATE	GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.				GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.				GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.			
	72	100	120	144	72	100	120	144	72	100	120	144	72	100	120	144	72	100	120	144	72	100	120	144	72	100	120	144	72	100	120	144				
3.600-10	3.605	63°	57°	32°	3.600	52°	37°	3.608	57°	32°	3.605	53°	36°	3.657	59°	31°	3.657	59°	31°	3.657	59°	31°	3.657	59°	31°	3.657	59°	31°	3.657	59°	31°	3.657	59°	31°		
3.600-20	3.612	64°	58°	32°	3.612	52°	37°	3.618	58°	32°	3.618	53°	37°	3.667	59°	30°	3.667	59°	30°	3.667	59°	30°	3.667	59°	30°	3.667	59°	30°	3.667	59°	30°	3.667	59°	30°		
3.620-30	3.620	64°	58°	31°	3.623	53°	37°	3.628	58°	31°	3.635	53°	36°	3.670	54°	36°	3.670	54°	36°	3.670	54°	36°	3.670	54°	36°	3.670	54°	36°	3.670	54°	36°	3.670	54°	36°		
3.630-40	3.635	64°	58°	31°	3.635	53°	36°	3.638	58°	31°	3.647	53°	36°	3.682	54°	35°	3.682	54°	35°	3.682	54°	35°	3.682	54°	35°	3.682	54°	35°	3.682	54°	35°	3.682	54°	35°		
3.640-50	3.642	65°	58°	31°	3.647	53°	36°	3.647	58°	31°	3.659	53°	36°	3.693	54°	35°	3.693	54°	35°	3.693	54°	35°	3.693	54°	35°	3.693	54°	35°	3.693	54°	35°	3.693	54°	35°		
3.650-60	3.657	65°	58°	31°	3.659	53°	36°	3.657	59°	31°	3.669	53°	36°	3.705	54°	35°	3.705	54°	35°	3.705	54°	35°	3.705	54°	35°	3.705	54°	35°	3.705	54°	35°	3.705	54°	35°		
3.660-70	3.664	65°	58°	31°	3.667	53°	36°	3.667	59°	30°	3.676	53°	36°	3.716	55°	35°	3.716	55°	35°	3.716	55°	35°	3.716	55°	35°	3.716	55°	35°	3.716	55°	35°	3.716	55°	35°		
3.670-80	3.672	66°	58°	31°	3.676	53°	36°	3.676	59°	30°	3.686	53°	36°	3.728	55°	34°	3.728	55°	34°	3.728	55°	34°	3.728	55°	34°	3.728	55°	34°	3.728	55°	34°	3.728	55°	34°		
3.680-90	3.686	66°	58°	31°	3.686	53°	36°	3.686	59°	30°	3.695	53°	36°	3.739	55°	34°	3.739	55°	34°	3.739	55°	34°	3.739	55°	34°	3.739	55°	34°	3.739	55°	34°	3.739	55°	34°		
3.690-00	3.699	67°	58°	31°	3.699	53°	36°	3.695	60°	30°	3.704	53°	36°	3.750	55°	34°	3.750	55°	34°	3.750	55°	34°	3.750	55°	34°	3.750	55°	34°	3.750	55°	34°	3.750	55°	34°		
3.700-10	3.706	67°	58°	31°	3.704	53°	36°	3.704	60°	29°	3.714	53°	36°	3.761	55°	34°	3.761	55°	34°	3.761	55°	34°	3.761	55°	34°	3.761	55°	34°	3.761	55°	34°	3.761	55°	34°		
3.710-20	3.712	67°	58°	31°	3.712	53°	36°	3.714	60°	29°	3.724	53°	36°	3.769	55°	34°	3.769	55°	34°	3.769	55°	34°	3.769	55°	34°	3.769	55°	34°	3.769	55°	34°	3.769	55°	34°		
3.720-30	3.726	68°	58°	31°	3.728	53°	36°	3.728	60°	29°	3.738	53°	36°	3.784	55°	34°	3.784	55°	34°	3.784	55°	34°	3.784	55°	34°	3.784	55°	34°	3.784	55°	34°	3.784	55°	34°		
3.730-40	3.739	68°	58°	31°	3.739	53°	36°	3.732	61°	29°	3.742	53°	36°	3.789	55°	34°	3.789	55°	34°	3.789	55°	34°	3.789	55°	34°	3.789	55°	34°	3.789	55°	34°	3.789	55°	34°		
3.740-50	3.745	68°	58°	31°	3.745	53°	36°	3.749	61°	28°	3.759	53°	36°	3.794	55°	34°	3.794	55°	34°	3.794	55°	34°	3.794	55°	34°	3.794	55°	34°	3.794	55°	34°	3.794	55°	34°		
3.750-60	3.752	69°	58°	31°	3.752	53°	36°	3.759	61°	28°	3.769	53°	36°	3.804	55°	34°	3.804	55°	34°	3.804	55°	34°	3.804	55°	34°	3.804	55°	34°	3.804	55°	34°	3.804	55°	34°		
3.760-70	3.764	69°	58°	31°	3.764	53°	36°	3.768	62°	28°	3.778	53°	36°	3.815	55°	34°	3.815	55°	34°	3.815	55°	34°	3.815	55°	34°	3.815	55°	34°	3.815	55°	34°	3.815	55°	34°		
3.770-80	3.777	70°	58°	31°	3.777	53°	36°	3.776	62°	27°	3.786	53°	36°	3.827	55°	34°	3.827	55°	34°	3.827	55°	34°	3.827	55°	34°	3.827	55°	34°	3.827	55°	34°	3.827	55°	34°		
3.780-90	3.788	70°	58°	31°	3.788	53°	36°	3.785	62°	27°	3.795	53°	36°	3.836	55°	34°	3.836	55°	34°	3.836	55°	34°	3.836	55°	34°	3.836	55°	34°	3.836	55°	34°	3.836	55°	34°		
3.790-00	3.794	70°	58°	31°	3.794	53°	36°	3.793	62°	27°	3.803	53°	36°	3.847	55°	34°	3.847	55°	34°	3.847	55°	34°	3.847	55°	34°	3.847	55°	34°	3.847	55°	34°	3.847	55°	34°		
3.800-10	3.800	71°	58°	31°	3.800	53°	36°	3.802	63°	27°	3.812	53°	36°	3.858	55°	34°	3.858	55°	34°	3.858	55°	34°	3.858	55°	34°	3.858	55°	34°	3.858	55°	34°	3.858	55°	34°		
3.810-20	3.811	71°	58°	31°	3.811	53°	36°	3.810	63°	26°	3.820	53°	36°	3.867	55°	34°	3.867	55°	34°	3.867	55°	34°	3.867	55°	34°	3.867	55°	34°	3.867	55°	34°	3.867	55°	34°		
3.820-30	3.822	72°	58°	31°	3.822	53°	36°	3.827	63°	26°	3.837	53°	36°	3.884	55°	34°	3.884	55°	34°	3.884	55°	34°	3.884	55°	34°	3.884	55°	34°	3.884	55°	34°	3.884	55°	34°		
3.830-40	3.833	72°	58°	31°	3.833	53°	36°	3.835	64°	26°	3.845	53°	36°	3.892	55°	34°	3.892	55°	34°	3.892	55°	34°	3.892	55°	34°	3.892	55°	34°	3.892	55°	34°	3.892	55°	34°		
3.840-50	3.843	73°	58°	31°	3.843	53°	36°	3.843	64°	25°	3.853	53°	36°	3.900	55°	34°	3.900	55°	34°	3.900	55°	34°	3.900	55°	34°	3.900	55°	34°	3.900	55°	34°	3.900	55°	34°		
3.850-60	3.854	73°	58°	31°	3.854	53°	36°	3.851	64°	25°	3.861	53°	36°	3.908	55°	34°	3.908	55°	34°	3.908	55°	34°	3.908	55°	34°	3.908	55°	34°	3.908	55°	34°	3.908	55°	34°		
3.860-70	3.863	74°	58°	31°	3.863	53°	36°	3.867	65°	25°	3.877	53°	36°	3.916	55°	34°	3.916	55°	34°	3.916	55°	34°	3.916	55°	34°	3.916	55°	34°	3.916	55°	34°	3.916	55°	34°		
3.870-80	3.873	74°	58°	31°	3.873	53°	36°	3.875	65°	24°	3.885	53°	36°	3.925	55°	34°	3.925	55°	34°	3.925	55°	34°	3.925	55°	34°	3.925	55°	34°	3.925	55°	34°	3.925	55°	34°		
3.880-90	3.882	75°	58°	31°	3.882	53°	36°	3.883	65°	24°	3.893	53°	36°	3.934	55°	34°	3.934	55°	34°	3.934	55°	34°	3.934	55°	34°	3.934	55°	34°	3.934	55°	34°	3.934	55°	34°		
3.890-00	3.891	75°	58°	31°	3.891	53°	36°	3.898	66°	24°	3.908	53°	36°	3.943	55°	34°	3.943	55°	34°	3.943	55°	34°	3.943	55°	34°	3.943	55°	34°	3.943	55°	34°	3.943	55°	34°		

LEADS FROM 4.200 TO 4.500

APPROXIMATE LEAD	GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.				GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.				GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.																																																																																																																																																																																																																																																																																																	
	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100																																																																																																																																																																																																																																																																																				
4.200-10	4.206	4.214	4.221	4.228	4.235	4.242	4.249	4.256	4.263	4.270	4.277	4.284	4.291	4.298	4.305	4.312	4.319	4.326	4.333	4.340	4.347	4.354	4.361	4.368	4.375	4.382	4.389	4.396	4.403	4.410	4.417	4.424	4.431	4.438	4.445	4.452	4.459	4.466	4.473	4.480	4.487	4.494	4.501	4.508	4.515	4.522	4.529	4.536	4.543	4.550	4.557	4.564	4.571	4.578	4.585	4.592	4.599	4.606	4.613	4.620	4.627	4.634	4.641	4.648	4.655	4.662	4.669	4.676	4.683	4.690	4.697	4.704	4.711	4.718	4.725	4.732	4.739	4.746	4.753	4.760	4.767	4.774	4.781	4.788	4.795	4.802	4.809	4.816	4.823	4.830	4.837	4.844	4.851	4.858	4.865	4.872	4.879	4.886	4.893	4.900	4.907	4.914	4.921	4.928	4.935	4.942	4.949	4.956	4.963	4.970	4.977	4.984	4.991	4.998	5.005	5.012	5.019	5.026	5.033	5.040	5.047	5.054	5.061	5.068	5.075	5.082	5.089	5.096	5.103	5.110	5.117	5.124	5.131	5.138	5.145	5.152	5.159	5.166	5.173	5.180	5.187	5.194	5.201	5.208	5.215	5.222	5.229	5.236	5.243	5.250	5.257	5.264	5.271	5.278	5.285	5.292	5.299	5.306	5.313	5.320	5.327	5.334	5.341	5.348	5.355	5.362	5.369	5.376	5.383	5.390	5.397	5.404	5.411	5.418	5.425	5.432	5.439	5.446	5.453	5.460	5.467	5.474	5.481	5.488	5.495	5.502	5.509	5.516	5.523	5.530	5.537	5.544	5.551	5.558	5.565	5.572	5.579	5.586	5.593	5.600	5.607	5.614	5.621	5.628	5.635	5.642	5.649	5.656	5.663	5.670	5.677	5.684	5.691	5.698	5.705	5.712	5.719	5.726	5.733	5.740	5.747	5.754	5.761	5.768	5.775	5.782	5.789	5.796	5.803	5.810	5.817	5.824	5.831	5.838	5.845	5.852	5.859	5.866	5.873	5.880	5.887	5.894	5.901	5.908	5.915	5.922	5.929	5.936	5.943	5.950	5.957	5.964	5.971	5.978	5.985	5.992	5.999	6.006	6.013	6.020	6.027	6.034	6.041	6.048	6.055	6.062	6.069	6.076	6.083	6.090	6.097	6.104	6.111	6.118	6.125	6.132	6.139	6.146	6.153	6.160	6.167	6.174	6.181	6.188	6.195	6.202	6.209	6.216	6.223	6.230	6.237	6.244	6.251	6.258	6.265	6.272	6.279	6.286	6.293	6.300	6.307	6.314	6.321	6.328	6.335	6.342	6.349	6.356	6.363	6.370	6.377	6.384	6.391	6.398	6.405	6.412	6.419	6.426	6.433	6.440	6.447	6.454

LEADS FROM 4.800 TO 5.100

APPROXIMATE LEAD	GEAR ON WORM										GEAR ON SCREW										VERTICAL ATT.																			
	GEAR ON WORM					GEAR ON SCREW					ANGLE TO SET SPIRAL HEAD					VERTICAL ATT.					GEAR ON WORM					GEAR ON SCREW					ANGLE TO SET SPIRAL HEAD					VERTICAL ATT.				
	60	72	90	100	120	60	72	90	100	120	60	72	90	100	120	60	72	90	100	120	60	72	90	100	120	60	72	90	100	120	60	72	90	100	120					
4.800-10	4.808	4.810	4.812	4.814	4.816	4.818	4.820	4.822	4.824	4.826	4.828	4.830	4.832	4.834	4.836	4.838	4.840	4.842	4.844	4.846	4.848	4.850	4.852	4.854	4.856	4.858	4.860	4.862	4.864	4.866	4.868	4.870	4.872	4.874	4.876	4.878				
4.810-20	4.816	4.818	4.820	4.822	4.824	4.826	4.828	4.830	4.832	4.834	4.836	4.838	4.840	4.842	4.844	4.846	4.848	4.850	4.852	4.854	4.856	4.858	4.860	4.862	4.864	4.866	4.868	4.870	4.872	4.874	4.876	4.878	4.880	4.882	4.884	4.886				
4.820-30	4.824	4.826	4.828	4.830	4.832	4.834	4.836	4.838	4.840	4.842	4.844	4.846	4.848	4.850	4.852	4.854	4.856	4.858	4.860	4.862	4.864	4.866	4.868	4.870	4.872	4.874	4.876	4.878	4.880	4.882	4.884	4.886	4.888	4.890	4.892	4.894				
4.830-40	4.839	4.841	4.843	4.845	4.847	4.849	4.851	4.853	4.855	4.857	4.859	4.861	4.863	4.865	4.867	4.869	4.871	4.873	4.875	4.877	4.879	4.881	4.883	4.885	4.887	4.889	4.891	4.893	4.895	4.897	4.899	4.901	4.903	4.905	4.907					
4.840-50	4.846	4.848	4.850	4.852	4.854	4.856	4.858	4.860	4.862	4.864	4.866	4.868	4.870	4.872	4.874	4.876	4.878	4.880	4.882	4.884	4.886	4.888	4.890	4.892	4.894	4.896	4.898	4.900	4.902	4.904	4.906	4.908	4.910	4.912	4.914					
4.850-60	4.853	4.855	4.857	4.859	4.861	4.863	4.865	4.867	4.869	4.871	4.873	4.875	4.877	4.879	4.881	4.883	4.885	4.887	4.889	4.891	4.893	4.895	4.897	4.899	4.901	4.903	4.905	4.907	4.909	4.911	4.913	4.915	4.917	4.919	4.921					
4.860-70	4.865	4.867	4.869	4.871	4.873	4.875	4.877	4.879	4.881	4.883	4.885	4.887	4.889	4.891	4.893	4.895	4.897	4.899	4.901	4.903	4.905	4.907	4.909	4.911	4.913	4.915	4.917	4.919	4.921	4.923	4.925	4.927	4.929	4.931	4.933					
4.870-80	4.875	4.877	4.879	4.881	4.883	4.885	4.887	4.889	4.891	4.893	4.895	4.897	4.899	4.901	4.903	4.905	4.907	4.909	4.911	4.913	4.915	4.917	4.919	4.921	4.923	4.925	4.927	4.929	4.931	4.933	4.935	4.937	4.939	4.941	4.943					
4.880-90	4.881	4.883	4.885	4.887	4.889	4.891	4.893	4.895	4.897	4.899	4.901	4.903	4.905	4.907	4.909	4.911	4.913	4.915	4.917	4.919	4.921	4.923	4.925	4.927	4.929	4.931	4.933	4.935	4.937	4.939	4.941	4.943	4.945	4.947	4.949					
4.890-00	4.895	4.897	4.899	4.901	4.903	4.905	4.907	4.909	4.911	4.913	4.915	4.917	4.919	4.921	4.923	4.925	4.927	4.929	4.931	4.933	4.935	4.937	4.939	4.941	4.943	4.945	4.947	4.949	4.951	4.953	4.955	4.957	4.959	4.961	4.963					
4.900-10	4.902	4.904	4.906	4.908	4.910	4.912	4.914	4.916	4.918	4.920	4.922	4.924	4.926	4.928	4.930	4.932	4.934	4.936	4.938	4.940	4.942	4.944	4.946	4.948	4.950	4.952	4.954	4.956	4.958	4.960	4.962	4.964	4.966	4.968	4.970					
4.910-20	4.915	4.917	4.919	4.921	4.923	4.925	4.927	4.929	4.931	4.933	4.935	4.937	4.939	4.941	4.943	4.945	4.947	4.949	4.951	4.953	4.955	4.957	4.959	4.961	4.963	4.965	4.967	4.969	4.971	4.973	4.975	4.977	4.979	4.981	4.983					
4.920-30	4.924	4.926	4.928	4.930	4.932	4.934	4.936	4.938	4.940	4.942	4.944	4.946	4.948	4.950	4.952	4.954	4.956	4.958	4.960	4.962	4.964	4.966	4.968	4.970	4.972	4.974	4.976	4.978	4.980	4.982	4.984	4.986	4.988	4.990	4.992					
4.930-40	4.931	4.933	4.935	4.937	4.939	4.941	4.943	4.945	4.947	4.949	4.951	4.953	4.955	4.957	4.959	4.961	4.963	4.965	4.967	4.969	4.971	4.973	4.975	4.977	4.979	4.981	4.983	4.985	4.987	4.989	4.991	4.993	4.995	4.997	4.999					
4.940-50	4.946	4.948	4.950	4.952	4.954	4.956	4.958	4.960	4.962	4.964	4.966	4.968	4.970	4.972	4.974	4.976	4.978	4.980	4.982	4.984	4.986	4.988	4.990	4.992	4.994	4.996	4.998	5.000	5.002	5.004	5.006	5.008	5.010	5.012						
4.950-60	4.952	4.954	4.956	4.958	4.960	4.962	4.964	4.966	4.968	4.970	4.972	4.974	4.976	4.978	4.980	4.982	4.984	4.986	4.988	4.990	4.992	4.994	4.996	4.998	5.000	5.002	5.004	5.006	5.008	5.010	5.012	5.014	5.016	5.018						
4.960-70	4.964	4.966	4.968	4.970	4.972	4.974	4.976	4.978	4.980	4.982	4.984	4.986	4.988	4.990	4.992	4.994	4.996	4.998	5.000	5.002	5.004	5.006	5.008	5.010	5.012	5.014	5.016	5.018	5.020	5.022	5.024	5.026	5.028	5.030						
4.970-80	4.975	4.977	4.979	4.981	4.983	4.985	4.987	4.989	4.991	4.993	4.995	4.997	4.999	5.001	5.003	5.005	5.007	5.009	5.011	5.013	5.015	5.017	5.019	5.021	5.023	5.025	5.027	5.029	5.031	5.033	5.035	5.037	5.039	5.041	5.043					
4.980-90	4.986	4.988	4.990	4.992	4.994	4.996	4.998	5.000	5.002	5.004	5.006	5.008	5.010	5.012	5.014	5.016	5.018	5.020	5.022	5.024	5.026	5.028	5.030	5.032	5.034	5.036	5.038	5.040	5.042	5.044	5.046	5.048	5.050	5.052	5.054					
4.990-00	4.996	4.998	5.000	5.002	5.004	5.006	5.008	5.010	5.012	5.014	5.016	5.018	5.020	5.022	5.024	5.026	5.028	5.030	5.032	5.034	5.036	5.038	5.040	5.042	5.044	5.046	5.048	5.050	5.052	5.054	5.056	5.058	5.060	5.062	5.064					
5.000-10	5.001	5.003	5.005	5.007	5.009	5.011	5.013	5.015	5.017	5.019	5.021	5.023	5.025	5.027	5.029	5.031	5.033	5.035	5.037	5.039	5.041	5.043	5.045	5.047	5.049	5.051	5.053	5.055	5.057	5.059	5.061	5.063	5.065	5.067	5.069					
5.010-20	5.016	5.018	5.020	5.022	5.024	5.026	5.028	5.030	5.032	5.034	5.036	5.038	5.040	5.042	5.044	5.046	5.048	5.050	5.052	5.054	5.056	5.058	5.060	5.062	5.064	5.066	5.068	5.070	5.072	5.074	5.076	5.078	5.080	5.082	5.084					
5.020-30	5.025	5.027	5.029	5.031	5.033	5.035	5.037	5.039	5.041	5.043	5.045	5.047	5.049	5.051	5.053	5.055	5.057	5.059	5.061	5.063	5.065	5.067	5.069	5.071	5.073	5.075	5.077	5.079	5.081	5.083	5.085	5.087	5.089	5.091	5.093					
5.030-40	5.030	5.032	5.034	5.036	5.038	5.040	5.042	5.044	5.046	5.048	5.050	5.052	5.054	5.056	5.058	5.060	5.062	5.064	5.066	5.068	5.070	5.072	5.074	5.076	5.078	5.080	5.082	5.084	5.086	5.088	5.090	5.092	5.094	5.096	5.098					
5.040-50	5.043	5.045	5.047	5.049	5.051	5.053	5.055	5.057	5.059	5.061	5.063	5.065	5.067	5.069	5.071	5.073	5.075	5.077	5.079	5.081	5.083	5.085	5.087	5.089	5.091	5.093	5.095	5.097	5.099	5.101	5.103	5.105	5.107	5.109	5.111					
5.050-60	5.051	5.053	5.055	5.057	5.059	5.061	5.063	5.065	5.067	5.069	5.071	5.073	5.075	5.077	5.079	5.081	5.083	5.085	5.087	5.089	5.091	5.093	5.095	5.097	5.099	5.101	5.103	5.105	5.107	5.109	5.111	5.113	5.115	5.117	5.119					
5.060-70	5.060	5.062	5.064	5.066	5.068	5.070	5.072	5.074	5.076	5.078	5.080	5.082	5.084	5.086	5.088	5.090	5.092	5.094	5.096	5.098	5.100	5.102	5.104	5.106	5.108	5.110	5.112	5.114	5.116	5.118	5.120	5.122	5.124	5.126	5.128					
5.070-80	5.064	5.066	5.068	5.070	5.072	5.074	5.076	5.078	5.080	5.082	5.084	5.086	5.088	5.090	5.092	5.094	5.096	5.098	5.100	5.102	5.104	5.106	5.108	5.110	5.112	5.114	5.116	5.118	5.120	5.122	5.124	5.126	5.128	5.130	5.132					
5.080-90	5.064	5.066	5.068	5.070	5.072	5.074	5.076	5.078	5.080	5.082	5.084	5.086	5.088	5.090	5.092	5.094	5.096	5.098	5.100	5.102	5.104	5.106	5.108	5.110	5.112	5.114	5.116	5.118	5.120	5.122	5.124	5.126	5.128	5.130	5.132					
5.090-00	5.064	5.066	5.068	5.070	5.072	5.074	5.076	5.078	5.080	5.082	5.084	5.086	5.088	5.090	5.092	5.094	5.096	5.098	5.100	5.102	5.104	5.106	5.108	5.110	5.112	5.114	5.116	5.118	5.120	5.122	5.124	5.126	5.128	5.130	5.132					

LEADS FROM 5,400 TO 5,700

[illegible]

LEADS FROM 6.000 TO 6.600

[illegible]

LEADS FROM 7.200 TO 7.800

[illegible]

LEADS FROM 7.800 TO 8.400

APPROXIMATE LEAD	LEADS FROM 7.800 TO 8.400									
	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW	ANGLE TO SET SPIRAL HEAD	ANGLE TO SET VERTICAL ATT.	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW
7.800-20	7.816	60 29 1/2	60 29 1/2	7.801	55 35	7.801	55 35	7.801	55 35	7.801
7.820-40	7.835	61 29	61 29	7.825	55 34	7.825	55 34	7.825	55 34	7.825
7.840-60	7.854	61 28	61 28	7.849	55 34	7.849	55 34	7.849	55 34	7.849
7.860-80	7.873	61 28	61 28	7.872	55 34	7.872	55 34	7.872	55 34	7.872
7.880-00	7.891	61 28	61 28	7.896	56 34	7.896	56 34	7.896	56 34	7.896
7.900-20	7.910	62 28	62 28	7.919	56 33	7.919	56 33	7.919	56 33	7.919
7.920-40	7.928	62 27	62 27	7.942	56 33	7.942	56 33	7.942	56 33	7.942
7.940-60	7.946	62 27	62 27	7.965	56 33	7.965	56 33	7.965	56 33	7.965
7.960-80	7.964	62 27	62 27	7.987	57 33	7.987	57 33	7.987	57 33	7.987
7.980-00	7.982	63 27	63 27	8.010	57 32	8.010	57 32	8.010	57 32	8.010
8.000-20	8.017	63 26	63 26	8.032	57 32	8.032	57 32	8.032	57 32	8.032
8.020-40	8.034	63 26	63 26	8.055	57 32	8.055	57 32	8.055	57 32	8.055
8.040-60	8.052	64 26	64 26	8.077	58 32	8.077	58 32	8.077	58 32	8.077
8.060-80	8.069	64 25	64 25	8.099	58 31	8.099	58 31	8.099	58 31	8.099
8.080-00	8.086	64 25	64 25	8.119	58 31	8.119	58 31	8.119	58 31	8.119
8.100-20	8.119	65 25	65 25	8.142	58 31	8.142	58 31	8.142	58 31	8.142
8.120-40	8.136	65 24	65 24	8.163	59 31	8.163	59 31	8.163	59 31	8.163
8.140-60	8.152	65 24	65 24	8.185	59 30	8.185	59 30	8.185	59 30	8.185
8.160-80	8.168	65 24	65 24	8.206	59 30	8.206	59 30	8.206	59 30	8.206
8.180-00	8.184	66 24	66 24	8.227	59 30	8.227	59 30	8.227	59 30	8.227
8.200-20	8.216	66 23	66 23	8.249	60 30	8.249	60 30	8.249	60 30	8.249
8.220-40	8.230	67 23	67 23	8.269	60 29	8.269	60 29	8.269	60 29	8.269
8.240-60	8.246	67 22	67 22	8.289	60 29	8.289	60 29	8.289	60 29	8.289
8.260-80	8.277	67 22	67 22	8.300	60 29	8.300	60 29	8.300	60 29	8.300
8.280-00	8.292	67 22	67 22	8.330	61 29	8.330	61 29	8.330	61 29	8.330
8.300-20	8.306	68 22	68 22	8.350	61 28	8.350	61 28	8.350	61 28	8.350
8.320-40	8.335	68 21	68 21	8.370	61 28	8.370	61 28	8.370	61 28	8.370
8.340-60	8.350	68 21	68 21	8.392	69 20	8.392	69 20	8.392	69 20	8.392
8.360-80	8.364	69 21	69 21	8.400	69 20	8.400	69 20	8.400	69 20	8.400
8.380-00	8.376	69 21	69 21	8.400	69 20	8.400	69 20	8.400	69 20	8.400

LEADS FROM 8.400 TO 9.000

LEAD	GEAR ON WORM										GEAR ON SCREW										GEAR ON SET										GEAR ON WORM										GEAR ON SCREW										GEAR ON SET																																																																																																																																																																																																																																																																																																																																																																																																																																	
	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368	370	372	374	376	378	380	382	384	386	388	390	392	394	396	398	400	402	404	406	408	410	412	414	416	418	420	422	424	426	428	430	432	434	436	438	440	442	444	446	448	450	452	454	456	458	460	462	464	466	468	470	472	474	476	478	480	482	484	486	488	490	492	494	496	498	500	502	504	506	508	510	512	514	516	518	520	522	524	526	528	530	532	534	536	538	540	542	544	546	548	550	552	554	556	558	560	562	564	566	568	570	572	574	576	578	580	582	584	586	588	590	592	594	596	598	600	602	604	606	608	610	612	614	616	618	620	622	624	626	628	630	632	634	636	638	640	642	644	646	648	650	652	654	656	658	660	662	664	666	668	670	672	674	676	678	680	682	684	686	688	690	692	694	696	698	700	702	704	706	708	710	712	714	716	718	720	722	724	726	728	730	732	734	736	738	740	742	744	746	748	750	752	754	756	758	760	762	764	766	768	770	772	774	776	778	780	782	784	786	788	790	792	794	796	798	800	802	804	806	808	810	812	814	816	818	820	822	824	826	828	830	832	834	836	838	840	842	844	846	848	850	852	854	856	858	860	862	864	866	868	870	872	874	876	878	880	882	884	886	888	890	892	894	896	898	900	902	904	906	908	910	912	914	916	918	920	922	924	926	928	930	932	934	936	938	940	942	944	946	948	950	952	954	956	958	960	962	964	966	968	970	972	974	976	978	980	982	984	986	988	990	992	994	996	998
ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET	ANGLE TO SET																																																																																																																																																															

LEADS FROM 9.000 TO 9.600

APPROXIMATE LEAD	9.000-20										9.020-40										9.040-60										9.060-80										9.080-00										9.100-20										9.120-40										9.140-60										9.160-80										9.180-00										9.200-20										9.220-40										9.240-60										9.260-80										9.280-00										9.300-20										9.320-40										9.340-60										9.360-80										9.380-00										9.400-20										9.420-40										9.440-60										9.460-80										9.480-00										9.500-20										9.520-40										9.540-60										9.560-80										9.580-00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	100	94	88	82	76	70	64	58	52	46	40	34	28	22	16	10	4	0	360	354	348	342	336	330	324	318	312	306	300	294	288	282	276	270	264	258	252	246	240	234	228	222	216	210	204	198	192	186	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
GEAR ON WORM	100	94	88	82	76	70	64	58	52	46	40	34	28	22	16	10	4	0	360	354	348	342	336	330	324	318	312	306	300	294	288	282	276	270	264	258	252	246	240	234	228	222	216	210	204	198	192	186	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
GEAR ON SCREW	72	66	60	54	48	42	36	30	24	18	12	6	0	360	354	348	342	336	330	324	318	312	306	300	294	288	282	276	270	264	258	252	246	240	234	228	222	216	210	204	198	192	186	180	174	168	162	156	150	144	138	132	126	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
ANGLE TO SET	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63

LEADS FROM 9,600 TO 10,200

[illegible]

LEADS FROM 10.800 TO 11.400

LEAD	APPROXIMATE																															
	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW	ANGLE TO SET SPIRAL HEAD	VERTICAL ATT.	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW	ANGLE TO SET SPIRAL HEAD	VERTICAL ATT.	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW	ANGLE TO SET SPIRAL HEAD	VERTICAL ATT.	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW	ANGLE TO SET SPIRAL HEAD	VERTICAL ATT.	GEAR ON WORM	1ST ON STUD	2ND ON STUD	GEAR ON SCREW	ANGLE TO SET SPIRAL HEAD	VERTICAL ATT.		
10.800-20	86	48	10.809	70	19	10.801	62	27	10.810	56	33	10.807	51	38	10.807	47	42	10.806	44	46	10.825	41	49	10.822	37	52	10.822	37	52	10.822	37	52
10.820-40	86	48	10.825	70	19	10.826	62	27	10.841	56	33	10.843	52	38	10.843	47	42	10.854	44	45	10.880	41	48	10.883	38	52	10.883	38	52	10.883	38	52
10.840-60	86	48	10.840	71	19	10.850	63	27	10.872	57	33	10.880	52	37	10.880	47	42	10.903	44	45	10.934	41	48	10.944	38	51	10.944	38	51	10.944	38	51
10.860-80	86	48	10.873	71	18	10.875	63	26	10.872	57	33	10.880	52	37	10.880	47	42	10.903	44	45	10.934	41	48	10.944	38	51	10.944	38	51	10.944	38	51
10.880-00	86	48	10.889	71	18	10.898	63	26	10.872	57	33	10.880	52	37	10.880	47	42	10.903	44	45	10.934	41	48	10.944	38	51	10.944	38	51	10.944	38	51
10.900-20	86	48	10.904	72	18	10.920	63	26	10.903	57	32	10.917	52	37	10.917	47	42	10.903	44	45	10.934	41	48	10.944	38	51	10.944	38	51	10.944	38	51
10.920-40	86	48	10.934	72	17	10.944	64	26	10.933	57	32	10.933	52	37	10.933	47	42	10.951	44	45	10.988	41	48	10.988	38	51	10.988	38	51	10.988	38	51
10.940-60	86	48	10.950	72	17	10.964	64	26	10.963	57	32	10.963	52	37	10.963	47	42	10.951	44	45	10.988	41	48	10.988	38	51	10.988	38	51	10.988	38	51
10.960-80	86	48	10.964	73	17	10.977	64	25	10.963	57	32	10.963	52	37	10.963	47	42	10.951	44	45	10.988	41	48	10.988	38	51	10.988	38	51	10.988	38	51
10.980-00	86	48	10.992	73	16	10.990	64	25	10.993	58	32	10.989	53	37	10.989	47	42	10.951	44	45	10.988	41	48	10.988	38	51	10.988	38	51	10.988	38	51
11.000-20	86	48	11.007	73	16	11.013	64	25	10.993	58	32	10.989	53	37	10.989	47	42	10.951	44	45	10.988	41	48	10.988	38	51	10.988	38	51	10.988	38	51
11.020-40	86	48	11.021	74	16	11.036	65	25	11.022	58	31	11.025	53	36	11.025	48	41	11.000	45	45	11.040	42	48	11.040	38	51	11.040	38	51	11.040	38	51
11.040-60	86	48	11.049	74	15	11.058	65	24	11.052	58	31	11.060	53	36	11.060	48	41	11.047	45	44	11.080	42	48	11.080	38	51	11.080	38	51	11.080	38	51
11.060-80	86	48	11.075	75	15	11.082	65	24	11.082	58	31	11.097	53	36	11.097	48	41	11.094	45	44	11.124	39	51	11.124	39	51	11.124	39	51	11.124	39	51
11.080-00	86	48	11.088	75	14	11.080	65	24	11.082	58	31	11.097	53	36	11.097	48	41	11.094	45	44	11.124	39	51	11.124	39	51	11.124	39	51	11.124	39	51
11.100-20	86	48	11.100	75	14	11.102	65	24	11.111	59	31	11.132	54	36	11.132	49	41	11.142	45	44	11.172	42	47	11.172	42	47	11.172	42	47	11.172	42	47
11.120-40	86	48	11.125	75	14	11.124	66	24	11.111	59	31	11.132	54	36	11.132	49	41	11.142	45	44	11.172	42	47	11.172	42	47	11.172	42	47	11.172	42	47
11.140-60	86	48	11.148	76	13	11.145	66	23	11.140	59	30	11.167	54	35	11.167	49	41	11.142	45	44	11.172	42	47	11.172	42	47	11.172	42	47	11.172	42	47
11.160-80	86	48	11.171	77	13	11.167	66	23	11.170	59	30	11.167	54	35	11.167	49	41	11.142	45	44	11.172	42	47	11.172	42	47	11.172	42	47	11.172	42	47
11.180-00	86	48	11.194	77	12	11.187	66	23	11.198	59	30	11.198	54	35	11.198	49	41	11.190	46	44	11.220	43	47	11.220	43	47	11.220	43	47	11.220	43	47
11.200-20	86	48	11.215	78	12	11.208	67	23	11.226	60	29	11.226	54	35	11.226	49	41	11.226	46	44	11.253	43	47	11.253	43	47	11.253	43	47	11.253	43	47
11.220-40	86	48	11.235	78	11	11.230	67	22	11.226	60	29	11.226	54	35	11.226	49	41	11.226	46	44	11.253	43	47	11.253	43	47	11.253	43	47	11.253	43	47
11.240-60	86	48	11.255	79	11	11.250	67	22	11.254	60	29	11.254	55	35	11.254	50	39	11.254	46	44	11.283	43	47	11.283	43	47	11.283	43	47	11.283	43	47
11.260-80	86	48	11.273	79	10	11.270	67	22	11.282	60	29	11.282	55	35	11.282	50	39	11.283	46	44	11.310	43	47	11.310	43	47	11.310	43	47	11.310	43	47
11.280-00	86	48	11.292	80	10	11.290	68	22	11.282	60	29	11.282	55	35	11.282	50	39	11.283	46	44	11.310	43	47	11.310	43	47	11.310	43	47	11.310	43	47
11.300-20	86	48	11.310	81	21	11.310	68	21	11.310	60	29	11.310	55	34	11.310	50	39	11.310	46	44	11.330	43	47	11.330	43	47	11.330	43	47	11.330	43	47
11.320-40	86	48	11.330	81	21	11.330	68	21	11.338	61	29	11.338	55	34	11.338	50	39	11.330	46	44	11.359	43	47	11.359	43	47	11.359	43	47	11.359	43	47
11.340-60	86	48	11.350	82	21	11.350	68	21	11.358	61	29	11.358	55	34	11.358	50	39	11.359	43	47	11.389	43	47	11.389	43	47	11.389	43	47	11.389	43	47
11.360-80	86	48	11.369	82	21	11.369	69	21	11.366	61	28	11.366	55	34	11.366	50	39	11.366	43	47	11.396	43	47	11.396	43	47	11.396	43	47	11.396	43	47
11.380-00	86	48	11.388	82	20	11.388	69	20	11.388	61	28	11.388	55	34	11.388	50	39	11.388	43	47	11.418	43	47	11.418	43	47	11.418	43	47	11.418	43	47

LEADS FROM 12.000 TO 12.600

[illegible]

LEADS FROM 13.200 TO 13.800

LEAD	GEAR ON WORM										GEAR ON SCREW										GEAR ON SET										GEAR ON WORM										GEAR ON SCREW										GEAR ON SET																																																																																																																																																																																																																																																																																																																																																																																																																
	60	45	30	15	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450	465	480	495	510	525	540	555	570	585	600	615	630	645	660	675	690	705	720	735	750	765	780	795	810	825	840	855	870	885	900	915	930	945	960	975	990	1005	1020	1035	1050	1065	1080	1095	1110	1125	1140	1155	1170	1185	1200	1215	1230	1245	1260	1275	1290	1305	1320	1335	1350	1365	1380	1395	1410	1425	1440	1455	1470	1485	1500	1515	1530	1545	1560	1575	1590	1605	1620	1635	1650	1665	1680	1695	1710	1725	1740	1755	1770	1785	1800	1815	1830	1845	1860	1875	1890	1905	1920	1935	1950	1965	1980	1995	2010	2025	2040	2055	2070	2085	2100	2115	2130	2145	2160	2175	2190	2205	2220	2235	2250	2265	2280	2295	2310	2325	2340	2355	2370	2385	2400	2415	2430	2445	2460	2475	2490	2505	2520	2535	2550	2565	2580	2595	2610	2625	2640	2655	2670	2685	2700	2715	2730	2745	2760	2775	2790	2805	2820	2835	2850	2865	2880	2895	2910	2925	2940	2955	2970	2985	3000	3015	3030	3045	3060	3075	3090	3105	3120	3135	3150	3165	3180	3195	3210	3225	3240	3255	3270	3285	3300	3315	3330	3345	3360	3375	3390	3405	3420	3435	3450	3465	3480	3495	3510	3525	3540	3555	3570	3585	3600	3615	3630	3645	3660	3675	3690	3705	3720	3735	3750	3765	3780	3795	3810	3825	3840	3855	3870	3885	3900	3915	3930	3945	3960	3975	3990	4005	4020	4035	4050	4065	4080	4095	4110	4125	4140	4155	4170	4185	4200	4215	4230	4245	4260	4275	4290	4305	4320	4335	4350	4365	4380	4395	4410	4425	4440	4455	4470	4485	4500	4515	4530	4545	4560	4575	4590	4605	4620	4635	4650	4665	4680	4695	4710	4725	4740	4755	4770	4785	4800	4815	4830	4845	4860	4875	4890	4905	4920	4935	4950	4965	4980	4995	5010	5025	5040	5055	5070	5085	5100	5115	5130	5145	5160	5175	5190	5205	5220	5235	5250	5265	5280	5295	5310	5325	5340	5355	5370	5385	5400	5415	5430	5445	5460	5475	5490	5505	5520	5535	5550	5565	5580	5595	5610	5625	5640	5655	5670	5685	5700	5715	5730	5745	5760	5775	5790	5805	5820	5835	5850	5865	5880	5895	5910	5925	5940	5955	5970	5985	6000	6015	6030	6045	6060	6075	6090	6105	6120	6135	6150	6165	6180	6195	6210	6225	6240	6255	6270	6285	6300	6315	6330	6345	6360	6375	6390	6405	6420	6435	6450	6465	6480	6495	6510	6525	6540	6555	6570	6585	6600	6615	6630	6645	6660	6675	6690

LEADS FROM 14,400 TO 15,000

APPROXIMATE LEAD	GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.				GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.				GEAR ON WORM				GEAR ON SCREW				VERTICAL ATT.			
	64	32	16	8	64	32	16	8	64	32	16	8	64	32	16	8	64	32	16	8	64	32	16	8	64	32	16	8	64	32	16	8				
14.400-20	14.422	68	22		14.431	61	29		14.437	54	35		14.431	50	39		14.400	46	43		14.401	43	47		14.400	46	43		14.401	43	47					
14.420-40	14.448	68	21		14.466	61	28		14.480	55	35		14.431	50	39		14.460	46	43		14.469	43	46		14.460	46	43		14.469	43	46					
14.440-60	14.473	68	21		14.498	68	21		14.500	61	28		14.483	50	39		14.519	46	43		14.536	43	46		14.519	46	43		14.536	43	46					
14.460-80	14.500	61	28		14.522	69	21		14.534	61	28		14.536	50	39		14.579	47	43		14.602	43	46		14.579	47	43		14.602	43	46					
14.480-00	14.540	60	20		14.568	62	28		14.569	55	34		14.588	51	39		14.638	47	42		14.669	44	46		14.638	47	42		14.669	44	46					
14.500-20	14.602	62	27		14.636	62	27		14.654	56	34		14.640	51	38		14.697	47	42		14.734	44	45		14.697	47	42		14.734	44	45					
14.520-40	14.663	70	19		14.670	62	27		14.698	56	33		14.690	51	38		14.740	51	38		14.755	47	42		14.740	51	38		14.755	47	42					
14.540-60	14.706	71	19		14.702	63	27		14.733	63	26		14.740	51	38		14.792	52	38		14.813	48	42		14.792	52	38		14.813	48	42					
14.560-80	14.750	71	18		14.756	63	26		14.783	56	33		14.792	52	38		14.842	52	37		14.872	48	41		14.842	52	37		14.872	48	41					
14.580-00	14.814	72	18		14.793	72	18		14.829	64	26		14.892	64	25		14.908	57	32		14.930	48	41		14.892	64	25		14.930	48	41					
14.600-20	14.834	72	17		14.814	72	17		14.829	64	26		14.908	57	32		14.930	48	41		14.930	48	41		14.930	48	41		14.930	48	41					
14.620-40	14.860	72	17		14.834	72	17		14.854	72	17		14.923	64	25		14.953	65	25		14.953	65	25		14.953	65	25		14.953	65	25					
14.640-60	14.880	73	17		14.854	73	17		14.874	73	17		14.940	60	16		14.974	74	15		14.974	74	15		14.974	74	15		14.974	74	15					
14.660-80	14.900	73	16		14.874	73	16		14.894	73	16		14.960	60	16		14.990	74	15		14.990	74	15		14.990	74	15		14.990	74	15					
14.680-00	14.920	73	16		14.894	73	16		14.914	73	16		14.980	60	16		15.010	74	15		15.010	74	15		15.010	74	15		15.010	74	15					
14.700-20	14.940	73	16		14.914	73	16		14.934	73	16		15.000	60	16		15.030	74	15		15.030	74	15		15.030	74	15		15.030	74	15					
14.720-40	14.960	73	16		14.934	73	16		14.954	73	16		15.040	60	16		15.070	74	15		15.070	74	15		15.070	74	15		15.070	74	15					
14.740-60	14.980	73	16		14.954	73	16		14.974	73	16		15.060	60	16		15.090	74	15		15.090	74	15		15.090	74	15		15.090	74	15					
14.760-80	15.000	73	16		14.974	73	16		14.994	73	16		15.080	60	16		15.110	74	15		15.110	74	15		15.110	74	15		15.110	74	15					
14.780-00	15.020	73	16		14.994	73	16		15.014	73	16		15.100	60	16		15.130	74	15		15.130	74	15		15.130	74	15		15.130	74	15					
14.800-20	15.040	73	16		15.014	73	16		15.034	73	16		15.120	60	16		15.150	74	15		15.150	74	15		15.150	74	15		15.150	74	15					
14.820-40	15.060	73	16		15.034	73	16		15.054	73	16		15.140	60	16		15.170	74	15		15.170	74	15		15.170	74	15		15.170	74	15					
14.840-60	15.080	73	16		15.054	73	16		15.074	73	16		15.160	60	16		15.190	74	15		15.190	74	15		15.190	74	15		15.190	74	15					
14.860-80	15.100	73	16		15.074	73	16		15.094	73	16		15.180	60	16		15.210	74	15		15.210	74	15		15.210	74	15		15.210	74	15					
14.880-00	15.120	73	16		15.094	73	16		15.114	73	16		15.200	60	16		15.230	74	15		15.230	74	15		15.230	74	15		15.230	74	15					
14.900-20	15.140	73	16		15.114	73	16		15.134	73	16		15.220	60	16		15.250	74	15		15.250	74	15		15.250	74	15		15.250	74	15					
14.920-40	15.160	73	16		15.134	73	16		15.154	73	16		15.240	60	16		15.270	74	15		15.270	74	15		15.270	74	15		15.270	74	15					
14.940-60	15.180	73	16		15.154	73	16		15.174	73	16		15.260	60	16		15.290	74	15		15.290	74	15		15.290	74	15		15.290	74	15					
14.960-80	15.200	73	16		15.174	73	16		15.194	73	16		15.280	60	16		15.310	74	15		15.310	74	15		15.310	74	15		15.310	74	15					
14.980-00	15.220	73	16		15.194	73	16		15.214	73	16		15.300	60	16		15.330	74	15		15.330	74	15		15.330	74	15		15.330	74	15					

LEADS FROM 16.200 TO 17.400

APPROXIMATE LEAD	GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GEAR ON WORM				GE			
---------------------	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	--------------	--	--	--	----	--	--	--

LEADS FROM 18.600 TO 20.100

[illegible]

NATURAL SINES AND COSINES *

/	0°		1°		2°		3°		4°		/
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.00000	1.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	1.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	1.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	1.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	1.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	1.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	1.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	1.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	1.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	1.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	1.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99732	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.00843	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00989	.99995	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
/	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	/
	89°		88°		87°		86°		85°		

* Courtesy of the International Correspondence Schools.

NATURAL SINES AND COSINES

/	5°		6°		7°		8°		9°		/
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13940	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98949	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99121	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12128	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
/	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	/
	84°		83°		82°		81°		80°		

NATURAL SINES AND COSINES

/	10°		11°		12°		13°		14°		/
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98357	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	.19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
/	Cosine		Sine		Cosine		Sine		Cosine		/
	79°		78°		77°		76°		75°		

/	15°		16°		17°		18°		19°		/
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94544	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94535	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94527	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94518	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94509	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94499	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94489	53
8	.26107	.96532	.27785	.96062	.29460	.95562	.31123	.95033	.32777	.94479	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94469	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94389	43
18	.26387	.96455	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94879	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94833	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26										

NATURAL SINES AND COSINES

/	30°		31°		32°		33°		34°		
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53631	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82463	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.82000	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82952	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57309	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
/	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	/
	59°		58°		57°		56°		55°		

/	35°		36°		37°		38°		39°		/
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.57358	.81915	.57709	.80902	.58184	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.57722	.80885	.58205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.57745	.80867	.58228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.57769	.80850	.58251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.57793	.80833	.58274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.57816	.80816	.58298	.79776	.61681	.78711	.63045	.77625	55
6	.57501	.81815	.57840	.80799	.58321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.57863	.80782	.58344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.57887	.80765	.58367	.79723	.61749	.78658	.63113	.77568	52
9	.57572	.81765	.57910	.80748	.58390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.57934	.80730	.58414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.57957	.80713	.58437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.57981	.80696	.58460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.58004	.80679	.58483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.58028	.80662	.58506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.58051	.80644	.58529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.58074	.80627	.58553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.58098	.80610	.58576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.58121	.80593	.58599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.58145	.80576	.58622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.58168	.80558	.58645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.58192	.80541	.58668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.58215	.80524	.58691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.58238	.80507	.58714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.58261	.80490	.58737	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.58284	.80472	.58761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.58307	.80455	.58784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.58330	.80438	.58807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.58353	.80420	.58830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.58376	.80403	.58853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.58400	.80386	.58876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.58423	.80368	.58899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.58446	.80351	.58922	.79300	.62297	.78225	.63653	.77125	28
33	.58										

NATURAL SINES AND COSINES

/	40°		41°		42°		43°		44°		/
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.64279	.76604	.65606	.75471	.66013	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66035	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66056	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66078	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66099	.74237	.68285	.73055	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.66121	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.66143	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.66164	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.66186	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.66207	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.66229	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.66251	.74100	.68434	.72917	.69696	.71711	49
12	.64546	.76380	.65869	.75241	.66272	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.66294	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.66315	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.66337	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.66358	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.66380	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.66401	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.66423	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.66444	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.66466	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.66487	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.66509	.73865	.68688	.72677	.69946	.71467	37
24	.64812	.76154	.66131	.75011	.66530	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.66552	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.66573	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.66595	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66219	.74934	.66616	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.66638	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.66659	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.66680	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.66702	.73688	.68878	.72497	.70132	.71284	28
33	.65011	.75984	.66327	.74838	.66723	.73669	.68899	.72477	.70153	.71264	27
34	.65033	.75965	.66349	.74818	.66745	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.66766	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.66788	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.66809	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.66830	.73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.66851	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.66873	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.66894	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.66916	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.66937	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.66959	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.66980	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	.66610	.74586	.67001	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67023	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67044	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67065	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67087	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73214	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73194	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
/	49°		48°		47°		46°		45°		/
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	

NATURAL TANGENTS AND COTANGENTS

/	0°		1°		2°		3°		4°		/
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infinite	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	60
1	.00029	3437.5	.01775	56.3506	.03521	28.3094	.05270	18.9755	.07024	14.2411	59
2	.00058	1718.87	.01804	55.4115	.03550	28.1664	.05299	18.8711	.07051	14.1821	58
3	.00087	1145.94	.01833	54.4648	.03579	27.9372	.05328	18.7678	.07080	14.1235	57
4	.00116	859.43	.01862	53.5086	.03608	27.7117	.05357	18.6656	.07110	14.0655	56
5	.00145	687.549	.01891	52.5421	.03637	27.4890	.05387	18.5645	.07139	14.0079	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	.07168	13.9507	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	.07197	13.8937	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	.07227	13.8378	52
9	.00262	381.071	.02007	49.8157	.03754	26.6367	.05503	18.1708	.07256	13.7821	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	.07285	13.7267	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	.07314	13.6719	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	.07344	13.6174	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	.07373	13.5634	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	.07402	13.5098	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	.07431	13.4566	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05707	17.5205	.07461	13.4039	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	.07490	13.3515	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	.07519	13.2996	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	.07548	13.2480	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	.07578	13.1969	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	.07607	13.1461	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	.07636	13.0958	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	.07665	13.0458	37
24	.00698	143.377	.02444	40.9174	.04191	23.8593	.05941	16.8319	.07694	12.9962	36
25	.00727	137.507	.02473	40.4378	.04220	23.6945	.05970	16.7496	.07722	12.9469	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	.07753	12.8981	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06028	16.5874	.07782	12.8496	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5073	.07811	12.8014	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	.07841	12.7536	31
30	.00873	114.599	.02619	38.1885	.04366	22.9038	.06116	16.3499	.07870	12.7062	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	.07899	12.6591	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	.07929	12.6124	28
33	.00960	104.171	.02706	36.9505	.04454	22.4541	.06204	16.1190	.07958	12.5660	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	.07987	12.5199	26
35	.01018	98.219	.02764	36.1776	.04512	22.1640	.06262	15.9687	.08017	12.4742	25
36	.01047	95.485	.02793	35.8006	.04541	22.0217	.06291	15.8945	.08046	12.4288	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	.08075	12.3838	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	.08104	12.3390	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	.08134	12.2946	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	.08163	12.2505	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	.08192	12.2067	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	.08221	12.1632	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	.08251	12.1201	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	.08280	12.0772	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	.08309	12.0346	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	.08339	11.9923	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	.08368	11.9504	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	.08397	11.9087	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	.08426	11.8673	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	.08455	11.8262	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	.08485	11.7853	9
52	.01513	66.1053	.03259	30.6833	.05007	19.9702	.06759	14.7954	.08514	11.7448	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	.08544	11.7045	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	.08573	11.6645	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	.08602	11.6248	5
56	.01629	61.3852	.03375	29.6245	.05124	19.5156	.06876	14.5438	.08632	11.5853	4
57	.01658	60.3058	.03404	29.3711	.05153	19.4051	.06905	14.4823	.08661	11.5461	3
58	.01687	59.2589	.03434	29.1220	.05182	19.2959	.06934	14.4212	.08690	11.5072	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	.08720	11.4685	1
60	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	.08749	11.4301	0
/	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	/
	89°		88°		87°		86°		85°		

NATURAL TANGENTS AND COTANGENTS

°	5°		6°		7°		8°		9°		°
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	60
1	.08778	11.3919	.10540	9.48781	.12308	8.12481	.14084	7.10038	.15868	6.30189	59
2	.08807	11.3540	.10569	9.46141	.12338	8.10536	.14113	7.08546	.15898	6.29067	58
3	.08837	11.3163	.10599	9.43515	.12367	8.08600	.14143	7.07059	.15928	6.27829	57
4	.08866	11.2789	.10628	9.40904	.12397	8.06674	.14173	7.05579	.15958	6.26655	56
5	.08895	11.2417	.10657	9.38307	.12426	8.04756	.14202	7.04105	.15988	6.25486	55
6	.08925	11.2048	.10687	9.35724	.12456	8.02848	.14232	7.02637	.16017	6.24321	54
7	.08954	11.1681	.10716	9.33155	.12485	8.00948	.14262	7.01174	.16047	6.23160	53
8	.08983	11.1316	.10746	9.30599	.12515	7.99058	.14291	6.99718	.16077	6.22003	52
9	.09013	11.0954	.10775	9.28058	.12544	7.97176	.14321	6.98268	.16107	6.20851	51
10	.09042	11.0594	.10805	9.25530	.12574	7.95302	.14351	6.96823	.16137	6.19703	50
11	.09071	11.0237	.10834	9.23016	.12603	7.93438	.14381	6.95385	.16167	6.18559	49
12	.09101	10.9882	.10863	9.20516	.12633	7.91582	.14410	6.93952	.16196	6.17419	48
13	.09130	10.9529	.10893	9.18028	.12662	7.89734	.14440	6.92525	.16226	6.16283	47
14	.09159	10.9178	.10922	9.15554	.12692	7.87895	.14470	6.91104	.16256	6.15151	46
15	.09189	10.8829	.10952	9.13093	.12722	7.86064	.14499	6.89685	.16286	6.14023	45
16	.09218	10.8483	.10981	9.10646	.12751	7.84242	.14529	6.88278	.16316	6.12899	44
17	.09247	10.8139	.11011	9.08211	.12781	7.82428	.14559	6.86874	.16346	6.11779	43
18	.09277	10.7797	.11040	9.05789	.12810	7.80622	.14588	6.85475	.16376	6.10664	42
19	.09306	10.7457	.11070	9.03379	.12840	7.78825	.14618	6.84082	.16405	6.09552	41
20	.09335	10.7119	.11099	9.00983	.12869	7.77035	.14648	6.82694	.16435	6.08444	40
21	.09365	10.6783	.11128	8.98598	.12899	7.75254	.14678	6.81312	.16465	6.07340	39
22	.09394	10.6450	.11158	8.96227	.12929	7.73480	.14707	6.79936	.16495	6.06240	38
23	.09423	10.6118	.11187	8.93867	.12958	7.71715	.14737	6.78564	.16525	6.05143	37
24	.09453	10.5789	.11217	8.91520	.12988	7.69957	.14767	6.77199	.16555	6.04051	36
25	.09482	10.5462	.11246	8.89185	.13017	7.68208	.14796	6.75838	.16585	6.02962	35
26	.09511	10.5136	.11276	8.86862	.13047	7.66466	.14826	6.74483	.16615	6.01878	34
27	.09541	10.4813	.11305	8.84551	.13076	7.64732	.14856	6.73133	.16645	6.00797	33
28	.09570	10.4491	.11335	8.82252	.13106	7.63005	.14886	6.71789	.16674	5.99720	32
29	.09600	10.4172	.11364	8.79964	.13136	7.61287	.14915	6.70450	.16704	5.98646	31
30	.09629	10.3854	.11394	8.77689	.13165	7.59575	.14945	6.69116	.16734	5.97576	30
31	.09658	10.3538	.11423	8.75425	.13195	7.57872	.14975	6.67787	.16764	5.96510	29
32	.09688	10.3224	.11452	8.73172	.13224	7.56176	.15005	6.66463	.16794	5.95448	28
33	.09717	10.2913	.11482	8.70931	.13254	7.54487	.15034	6.65144	.16824	5.94390	27
34	.09746	10.2602	.11511	8.68701	.13284	7.52806	.15064	6.63831	.16854	5.93335	26
35	.09776	10.2294	.11541	8.66482	.13313	7.51132	.15094	6.62523	.16884	5.92283	25
36	.09805	10.1988	.11570	8.64275	.13343	7.49465	.15124	6.61219	.16914	5.91236	24
37	.09834	10.1683	.11600	8.62078	.13372	7.47806	.15153	6.59921	.16944	5.90191	23
38	.09864	10.1381	.11629	8.59893	.13402	7.46154	.15183	6.58627	.16974	5.89151	22
39	.09893	10.1080	.11659	8.57718	.13432	7.44509	.15213	6.57339	.17004	5.88114	21
40	.09923	10.0780	.11688	8.55555	.13461	7.42871	.15243	6.56055	.17033	5.87080	20
41	.09952	10.0483	.11718	8.53402	.13491	7.41240	.15272	6.54777	.17063	5.86051	19
42	.09981	10.0187	.11747	8.51259	.13521	7.39616	.15302	6.53503	.17093	5.85024	18
43	.10011	9.98931	.11777	8.49128	.13550	7.37999	.15332	6.52234	.17123	5.84001	17
44	.10040	9.96007	.11806	8.47007	.13580	7.36389	.15362	6.50970	.17153	5.82982	16
45	.10069	9.93101	.11836	8.44896	.13609	7.34786	.15391	6.49710	.17183	5.81966	15
46	.10099	9.90211	.11865	8.42795	.13639	7.33190	.15421	6.48456	.17213	5.80953	14
47	.10128	9.87338	.11895	8.40705	.13669	7.31600	.15451	6.47206	.17243	5.79944	13
48	.10158	9.84482	.11924	8.38625	.13698	7.30018	.15481	6.45961	.17273	5.78938	12
49	.10187	9.81641	.11954	8.36555	.13728	7.28442	.15511	6.44720	.17303	5.77936	11
50	.10216	9.78817	.11983	8.34496	.13758	7.26873	.15540	6.43484	.17333	5.76937	10
51	.10246	9.76009	.12013	8.32446	.13787	7.25310	.15570	6.42253	.17363	5.75941	9
52	.10275	9.73217	.12042	8.30406	.13817	7.23754	.15600	6.41026	.17393	5.74949	8
53	.10305	9.70441	.12072	8.28376	.13846	7.22204	.15630	6.39804	.17423	5.73960	7
54	.10334	9.67680	.12101	8.26355	.13876	7.20661	.15660	6.38587	.17453	5.72974	6
55	.10363	9.64935	.12131	8.24344	.13906	7.19125	.15689	6.37374	.17483	5.71992	5
56	.10393	9.62205	.12160	8.22344	.13935	7.17594	.15719	6.36165	.17513	5.71013	4
57	.10422	9.59490	.12190	8.20352	.13965	7.16071	.15749	6.34961	.17543	5.70037	3
58	.10452	9.56791	.12219	8.18370	.13995	7.14553	.15779	6.33761	.17573	5.69064	2
59	.10481	9.54106	.12249	8.16398	.14024	7.13042	.15809	6.32566	.17603	5.68094	1
60	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	.17633	5.67128	0
/	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	/
/	84°		83°		82°		81°		80°		/

NATURAL TANGENTS AND COTANGENTS

/	10°		11°		12°		13°		14°		/
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.17633	.567128	.19438	.514455	.21256	.470463	.23087	.433148	.24933	.410197	60
1	.17663	.566165	.19468	.513668	.21286	.469791	.23117	.432573	.24964	.410052	59
2	.17693	.565205	.19498	.512862	.21316	.469121	.23148	.432001	.24995	.410008	58
3	.17723	.564248	.19529	.512060	.21347	.468452	.23179	.431430	.25026	.409952	57
4	.17753	.563295	.19559	.511279	.21377	.467786	.23209	.430860	.25056	.409900	56
5	.17783	.562344	.19589	.510490	.21408	.467121	.23240	.430291	.25087	.409850	55
6	.17813	.561397	.19619	.509704	.21438	.466458	.23271	.429724	.25117	.409817	54
7	.17843	.560452	.19649	.508921	.21469	.465797	.23301	.429159	.25149	.409775	53
8	.17873	.559511	.19680	.508139	.21499	.465138	.23332	.428595	.25180	.409739	52
9	.17903	.558573	.19710	.507360	.21529	.464480	.23363	.428032	.25211	.409695	51
10	.17933	.557638	.19740	.506584	.21560	.463825	.23393	.427471	.25242	.409655	50
11	.17963	.556706	.19770	.505809	.21590	.463171	.23424	.426911	.25273	.409618	49
12	.17993	.555777	.19801	.505037	.21621	.462518	.23455	.426352	.25304	.409576	48
13	.18023	.554851	.19831	.504267	.21651	.461863	.23485	.425795	.25335	.409533	47
14	.18053	.553927	.19861	.503499	.21682	.461219	.23516	.425239	.25366	.409492	46
15	.18083	.553007	.19891	.502734	.21712	.460572	.23547	.424685	.25397	.409451	45
16	.18113	.552090	.19921	.501971	.21743	.459927	.23578	.424132	.25428	.409411	44
17	.18143	.551176	.19952	.501210	.21773	.459283	.23608	.423580	.25459	.409373	43
18	.18173	.550264	.19982	.500451	.21804	.458639	.23639	.423030	.25490	.409336	42
19	.18203	.549356	.20012	.499695	.21834	.458001	.23670	.422481	.25521	.409299	41
20	.18233	.548451	.20042	.498940	.21864	.457363	.23700	.421933	.25551	.409264	40
21	.18263	.547548	.20073	.498188	.21895	.456726	.23731	.421387	.25583	.409230	39
22	.18293	.546648	.20103	.497438	.21925	.456091	.23762	.420842	.25614	.409197	38
23	.18323	.545751	.20133	.496690	.21956	.455456	.23793	.420298	.25645	.409165	37
24	.18353	.544857	.20164	.495945	.21986	.454826	.23824	.419756	.25676	.409134	36
25	.18384	.543966	.20194	.495201	.22017	.454196	.23854	.419215	.25707	.409104	35
26	.18414	.543077	.20224	.494460	.22047	.453568	.23885	.418675	.25738	.409075	34
27	.18444	.542192	.20254	.493721	.22078	.452941	.23916	.418137	.25769	.409046	33
28	.18474	.541309	.20285	.492984	.22108	.452316	.23947	.417600	.25800	.409018	32
29	.18504	.540429	.20315	.492249	.22139	.451693	.23977	.417064	.25831	.408991	31
30	.18534	.539554	.20345	.491516	.22169	.451071	.24008	.416530	.25862	.408964	30
31	.18564	.538677	.20376	.490785	.22200	.450451	.24039	.415997	.25893	.408930	29
32	.18594	.537805	.20406	.490056	.22231	.449832	.24069	.415465	.25924	.408904	28
33	.18624	.536936	.20436	.489330	.22261	.449215	.24100	.414934	.25955	.408878	27
34	.18654	.536070	.20466	.488605	.22292	.448600	.24131	.414405	.25986	.408854	26
35	.18684	.535206	.20497	.487882	.22322	.447986	.24162	.413877	.26017	.408830	25
36	.18714	.534345	.20527	.487162	.22353	.447374	.24193	.413350	.26048	.408806	24
37	.18745	.533487	.20557	.486444	.22383	.446764	.24223	.412825	.26079	.408784	23
38	.18775	.532631	.20588	.485727	.22414	.446155	.24254	.412301	.26110	.408762	22
39	.18805	.531778	.20618	.485013	.22444	.445548	.24285	.411778	.26141	.408741	21
40	.18835	.530928	.20648	.484300	.22475	.444942	.24316	.411256	.26172	.408720	20
41	.18865	.530080	.20679	.483590	.22505	.444338	.24347	.410736	.26203	.408700	19
42	.18895	.529235	.20709	.482882	.22536	.443735	.24377	.410216	.26235	.408681	18
43	.18925	.528393	.20739	.482175	.22567	.443134	.24408	.409699	.26266	.408662	17
44	.18955	.527553	.20770	.481471	.22597	.442534	.24439	.409182	.26297	.408643	16
45	.18986	.526715	.20800	.480769	.22628	.441936	.24470	.408666	.26328	.408625	15
46	.19016	.525880	.20830	.480068	.22658	.441340	.24501	.408152	.26359	.408607	14
47	.19046	.525048	.20861	.479370	.22689	.440745	.24532	.407639	.26390	.408589	13
48	.19076	.524218	.20891	.478673	.22719	.440152	.24562	.407127	.26421	.408572	12
49	.19106	.523391	.20921	.477978	.22750	.439560	.24593	.406616	.26452	.408555	11
50	.19136	.522566	.20952	.477286	.22781	.438969	.24624	.406107	.26483	.408538	10
51	.19166	.521744	.20982	.476595	.22811	.438381	.24655	.405599	.26515	.408522	9
52	.19197	.520925	.21013	.475906	.22842	.437793	.24686	.405092	.26546	.408506	8
53	.19227	.520107	.21043	.475219	.22872	.437207	.24717	.404586	.26577	.408490	7
54	.19257	.519293	.21073	.474534	.22903	.436623	.24747	.404081	.26608	.408475	6
55	.19287	.518480	.21104	.473851	.22934	.436040	.24778	.403578	.26639	.408460	5
56	.19317	.517671	.21134	.473170	.22964	.435459	.24809	.403076	.26670	.408445	4
57	.19347	.516863	.21164	.472490	.22995	.434879	.24840	.402574	.26701	.408431	3
58	.19378	.516058	.21195	.471813	.23026	.434300	.24871	.402074	.26733	.408417	2
59	.19408	.515256	.21225	.471137	.23056	.433723	.24902	.401576	.26764	.408404	1
60	.19438	.514455	.21256	.470463	.23087	.433148	.24933	.401078	.26795	.408391	0
/	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	/
	79°		78°		77°		76°		75°		

NATURAL TANGENTS AND COTANGENTS

/	15°		16°		17°		18°		19°		/
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.26795	3.73205	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90041	60
1	.26826	3.73174	.28706	3.48739	.30605	3.26715	.32524	3.07464	.34465	2.90147	59
2	.26857	3.73143	.28738	3.48737	.30637	3.26346	.32556	3.07160	.34498	2.89873	58
3	.26888	3.73110	.28769	3.48735	.30669	3.25967	.32588	3.06857	.34530	2.89606	57
4	.26920	3.73174	.28800	3.48726	.30700	3.25579	.32621	3.06554	.34563	2.89327	56
5	.26951	3.73104	.28832	3.48737	.30732	3.25202	.32653	3.06252	.34596	2.89055	55
6	.26982	3.73061	.28864	3.48658	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.27013	3.73018	.28895	3.48608	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.27044	3.69761	.28927	3.45703	.30828	3.24383	.32749	3.05340	.34693	2.88240	52
9	.27076	3.69535	.28958	3.45327	.30860	3.24049	.32782	3.05040	.34726	2.87970	51
10	.27107	3.68909	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.27138	3.68485	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.27169	3.68061	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.27201	3.67638	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.27232	3.67217	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.27263	3.66796	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.27294	3.66376	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.27326	3.65957	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.27357	3.65538	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.27388	3.65121	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.27419	3.64705	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.27451	3.64289	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.27482	3.63874	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.27513	3.63461	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.27545	3.63048	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.27576	3.62636	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.27607	3.62224	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.27638	3.61814	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.27670	3.61405	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.27701	3.60996	.29590	3.37955	.31498	3.17481	.33427	2.99155	.35379	2.82653	31
30	.27732	3.60588	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82390	30
31	.27764	3.60181	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82131	29
32	.27795	3.59775	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.27826	3.59370	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.27858	3.58966	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.27889	3.58562	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.27921	3.58160	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.27952	3.57758	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.27983	3.57357	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.28015	3.56957	.29906	3.34377	.31818	3.14288	.33751	2.96283	.35707	2.80059	21
40	.28046	3.56557	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.28077	3.56159	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.28109	3.55761	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.28140	3.55364	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.28172	3.54968	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.28203	3.54573	.30097	3.32264	.32010	3.12400	.33945	2.94591	.35904	2.78523	15
46	.28234	3.54179	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.28266	3.53785	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78013	13
48	.28297	3.53393	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.28329	3.53001	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.28360	3.52609	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.28391	3.52219	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.28423	3.51829	.30319	3.29829	.32235	3.10223	.34173	2.92634	.36134	2.76750	8
53	.28454	3.51441	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76499	7
54	.28486	3.51053	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.28517	3.50666	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75994	5
56	.28549	3.50279	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.28580	3.49894	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.28612	3.49509	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.28643	3.49125	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
/	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	/
	74°		73°		72°		71°		70°		

NATURAL TANGENTS AND COTANGENTS

/	20°		21°		22°		23°		24°		/
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	.44558	2.24428	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42510	2.35205	.44593	2.24252	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42531	2.35015	.44627	2.24077	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42555	2.34825	.44662	2.23902	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42579	2.34635	.44697	2.23727	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42604	2.34447	.44732	2.23553	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42628	2.34258	.44767	2.23378	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	.44802	2.23204	52
9	.36694	2.72525	.38687	2.58484	.40707	2.45655	.42757	2.33881	.44837	2.23030	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	.44872	2.22857	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	.44907	2.22683	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	.44942	2.22510	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	.44977	2.22337	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	.45012	2.22164	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	.45047	2.21992	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32569	.45082	2.21819	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	.45117	2.21647	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	.45152	2.21475	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	.45187	2.21304	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	.45222	2.21132	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	.45257	2.20961	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	.45292	2.20790	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43239	2.31271	.45327	2.20619	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	.45362	2.20448	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	.45397	2.20277	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	.45432	2.20106	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	.45467	2.19938	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	.45502	2.19769	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	.45537	2.19599	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	.45573	2.19430	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	.45608	2.19261	29
32	.37455	2.66989	.39459	2.53432	.41489	2.41025	.43550	2.29619	.45643	2.19092	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	.45678	2.18923	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	.45713	2.18755	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	.45748	2.18587	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	.45784	2.18419	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	.45819	2.18249	23
38	.37654	2.65576	.39660	2.52143	.41694	2.39841	.43758	2.28528	.45854	2.18082	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	.45889	2.17916	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	.45924	2.17749	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	.45960	2.17582	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	.45995	2.17416	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	.46030	2.17249	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	.46065	2.17083	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	.46101	2.16917	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	.46136	2.16751	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	.46171	2.16585	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	.46206	2.16420	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	.46242	2.16255	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	.46277	2.16090	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	.46312	2.15925	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	.46348	2.15760	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	.46383	2.15596	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	.46418	2.15432	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	.46454	2.15268	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	.46489	2.15104	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	.46525	2.14940	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	.46560	2.14777	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	.46595	2.14614	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	.46631	2.14451	0
/	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	/
	69°		68°		67°		66°		65°		

NATURAL TANGENTS AND COTANGENTS

°	40°		41°		42°		43°		44°		°
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	.96625	1.03493	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	.96681	1.03433	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	.96738	1.03372	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	.96794	1.03312	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	.96850	1.03252	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	.96907	1.03192	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	.96963	1.03132	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	.97020	1.03072	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	.97076	1.03012	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	.97133	1.02952	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	.97189	1.02892	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	.97246	1.02832	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	.97302	1.02772	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	.97359	1.02713	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	.97416	1.02653	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	.97472	1.02593	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	.97529	1.02533	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	.97586	1.02474	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	.97643	1.02414	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	.97700	1.02355	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	.97756	1.02295	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	.97813	1.02236	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	.97870	1.02176	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	.97927	1.02117	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	.97984	1.02057	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	.98041	1.01998	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	.98098	1.01939	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	.98155	1.01879	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	.98213	1.01820	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	.98270	1.01761	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	.98327	1.01702	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	.98384	1.01642	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	.98441	1.01583	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	.98499	1.01524	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	.98556	1.01465	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	.98613	1.01406	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	.98671	1.01347	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	.98728	1.01288	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	.98786	1.01229	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	.98843	1.01170	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	.98901	1.01112	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	.98958	1.01053	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	.99016	1.00994	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	.99073	1.00935	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	.99131	1.00876	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	.99189	1.00818	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	.99247	1.00759	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	.99304	1.00701	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	.99362	1.00642	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	.99420	1.00583	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	.99478	1.00525	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	.99536	1.00467	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	.99594	1.00408	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	.99652	1.00350	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	.99710	1.00291	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	.99768	1.00233	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	.99826	1.00175	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	.99884	1.00116	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	.99942	1.00058	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	1.00000	1.00000	0
°	Cotang Tang		Cotang Tang		Cotang Tang		Cotang Tang		Cotang Tang		°
	49°		48°		47°		46°		45°		

INDEX MOVEMENTS OF SPIRAL HEAD **FOR** **LONGITUDINAL GRADUATING ON A MILLING MACHINE**

MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE
.0001275	1	49	.0006377	5	49	.0011479	9	49	.0016447	5	19
.0001330	1	47	.0006410	4	39	.0011574	5	27	.0016581	13	49
.0001454	1	43	.0006465	3	29	.0011628	8	43	.0016666	4	15
.0001524	1	41	.0006579	2	19	.0011718	3	16	.0016768	11	41
.0001603	1	39	.0006649	5	47	.0011824	7	37	.0016892	10	37
.0001689	1	37	.0006757	4	37	.0011905	4	21	.0017045	9	33
.0001894	1	33	.0006944	3	27	.0011968	9	47	.0017241	8	29
.0002016	1	31	.0006944	2	18	.0012096	6	31	.0017288	13	47
.0002155	1	29	.0007268	5	43	.0012195	8	41	.0017361	5	18
.0002315	1	27	.0007353	2	17	.0012500	4	20	.0017442	12	43
.0002551	2	49	.0007576	4	33	.0012500	3	15	.0017628	11	39
.0002660	2	47	.0007622	5	41	.0012755	10	49	.0017857	6	21
.0002717	1	23	.0007653	6	49	.0012820	8	39	.0017857	14	49
.0002907	2	43	.0007813	2	16	.0012930	6	29	.0018144	9	31
.0002976	1	21	.0007979	6	47	.0013081	9	43	.0018292	12	41
.0003049	2	41	.0008012	5	39	.0013158	4	19	.0018382	5	17
.0003125	1	20	.0008064	4	31	.0013257	7	33	.0018518	8	27
.0003205	2	39	.0008152	3	23	.0013298	10	47	.0018581	11	37
.0003289	1	19	.0008333	2	15	.0013513	8	37	.0018617	14	47
.0003378	2	37	.0008446	5	37	.0013587	5	23	.001875	6	20
.0003472	1	18	.0008621	4	29	.0013722	9	41	.0018896	13	43
.0003676	1	17	.0008721	6	43	.0013888	6	27	.0018939	10	33
.0003788	2	33	.0008929	7	49	.0013888	4	18	.0019021	7	23
.0003826	3	49	.0008929	3	21	.0014031	11	49	.0019132	15	49
.0003906	1	16	.0009146	6	41	.0014113	7	31	.0019231	12	39
.0003989	3	47	.0009259	4	27	.0014422	9	39	.0019396	9	29
.0004032	2	31	.0009308	7	47	.0014535	10	43	.0019532	5	16
.0004167	1	15	.0009375	3	20	.0014628	11	47	.0019737	6	19
.0004310	2	29	.0009469	5	33	.0014706	4	17	.0019818	13	41
.0004361	3	43	.0009616	6	39	.0014881	5	21	.0019947	15	47
.0004573	3	41	.0009869	3	19	.0015086	7	29	.0020161	10	31
.0004630	2	27	.0010081	5	31	.0015152	8	33	.0020271	12	37
.0004808	3	39	.0010136	6	37	.0015202	9	37	.002035	14	43
.0005068	3	37	.0010174	7	43	.0015244	10	41	.0020485	16	49
.0005102	4	49	.0010204	8	49	.0015306	12	49	.0020833	13	39
.0005319	4	47	.0010417	3	18	.0015625	5	20	.0020833	5	15
.0005435	2	23	.0010638	8	47	.0015625	4	16	.0020833	11	33
.0005682	3	33	.0010671	7	41	.0015957	12	47	.0020833	9	27
.0005814	4	43	.0010776	5	29	.0015989	11	43	.0020833	7	21
.0005952	2	21	.0010869	4	23	.0016026	10	39	.0020833	6	18
.0006048	3	31	.0011029	3	17	.0016128	8	31	.0021277	16	47
.0006098	4	41	.0011218	7	39	.0016204	7	27	.0021342	14	41
.0006250	2	20	.0011363	6	33	.0016303	6	23	.0021552	10	29

For method of using the above table see pages 183 and 184.

**INDEX MOVEMENTS OF SPIRAL HEAD
FOR
LONGITUDINAL GRADUATING ON A MILLING MACHINE**

MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE
.0021682	17	49	.0026785	9	21	.0032014	21	41	.003699	29	49
.0021738	8	23	.0026785	21	49	.003205	20	39	.0037038	16	27
.0021802	15	43	.0027028	16	37	.0032095	19	37	.0037163	22	37
.0021875	7	20	.0027174	10	23	.0032197	17	33	.0037234	28	47
.002196	13	37	.0027243	17	39	.0032257	16	31	.003750	12	20
.0022059	6	17	.0027344	7	16	.0032327	15	29	.003750	9	15
.0022176	11	31	.002744	18	41	.0032408	14	27	.0037793	26	43
.0022436	14	39	.0027618	19	43	.0032607	12	23	.0037878	20	33
.0022607	17	47	.0027777	8	18	.0032738	11	21	.0038043	14	23
.0022728	12	33	.0027777	12	27	.0032895	10	19	.0038112	25	41
.0022866	15	41	.0027925	21	47	.0033088	9	17	.0038195	11	18
.0022959	18	49	.0028017	13	29	.0033164	26	49	.0038265	30	49
.0023027	7	19	.002806	22	49	.0033245	25	47	.0038305	19	31
.0023148	10	27	.0028125	9	20	.0033333	8	15	.003846	24	39
.0023257	16	43	.0028225	14	31	.0033431	23	43	.0038564	29	47
.0023438	6	16	.0028409	15	33	.0033538	22	41	.0038692	13	21
.0023649	14	37	.0028717	17	37	.0033654	21	39	.0038794	18	29
.0023706	11	29	.0028846	18	39	.0033784	20	37	.0038853	23	37
.0023809	8	21	.0028963	19	41	.0034091	18	33	.0039063	10	16
.0023937	18	47	.002907	20	43	.0034273	17	31	.0039246	27	43
.0024038	15	39	.0029167	7	15	.0034375	11	20	.0039352	17	27
.0024192	12	31	.0029256	22	47	.0034439	27	49	.0039475	12	19
.0024235	19	49	.0029337	23	49	.0034482	16	29	.003954	31	49
.0024306	7	18	.0029412	8	17	.0034574	26	47	.0039636	26	41
.002439	16	41	.0029605	9	19	.0034722	10	18	.0039773	21	33
.0024455	9	23	.0029762	10	21	.0034722	15	27	.0039894	30	47
.0024622	13	33	.002989	11	23	.0034885	24	43	.0040064	25	39
.002471	17	43	.0030094	13	27	.0035063	23	41	.0040322	20	31
.00250	8	20	.0030172	14	29	.0035156	9	16	.0040443	11	17
.00250	6	15	.0030241	15	31	.0035255	22	39	.0040541	24	37
.0025266	19	47	.0030303	16	33	.0035325	13	23	.0040625	13	20
.0025339	15	37	.0030406	18	37	.0035474	21	37	.00407	28	43
.0025463	11	27	.0030448	19	39	.0035714	12	21	.0040759	15	23
.002551	20	49	.0030488	20	41	.0035714	28	49	.0040817	32	49
.002564	16	39	.0030524	21	43	.0035904	27	47	.0040948	19	29
.0025736	7	17	.0030586	23	47	.0035984	19	33	.004116	27	41
.0025862	12	29	.0030611	24	49	.0036186	11	19	.0041223	31	47
.0025915	17	41	.003125	9	18	.0036289	18	31	.0041666	22	33
.0026164	18	43	.003125	10	20	.0036339	25	43	.0041666	14	21
.0026209	13	31	.003125	8	16	.0036585	24	41	.0041666	18	27
.0026316	8	19	.0031889	25	49	.0036637	17	29	.0041666	12	18
.0026515	14	33	.0031915	24	47	.0036765	10	17	.0041666	10	15
.0026596	20	47	.0031978	22	43	.0036858	23	39	.0041666	26	39

For method of using the above table see pages 183 and 184.

INDEX MOVEMENTS OF SPIRAL HEAD FOR LONGITUDINAL GRADUATING ON A MILLING MACHINE

MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE	MOVEMENT OF TABLE	HOLES	CIRCLE
.0042091	33	49	.0047256	31	41	.0052327	36	43	.0057433	34	37
.0042152	29	43	.0047299	28	37	.0052365	31	37	.0057692	36	39
.0042232	25	37	.0047349	25	33	.0052419	26	31	.0057874	25	27
.0042338	21	31	.0047414	22	29	.0052635	16	19	.0057927	38	41
.0042553	32	47	.004762	16	21	.0052884	33	39	.0058142	40	43
.0042685	28	41	.0047796	13	17	.005303	28	33	.0058187	27	29
.0042765	13	19	.0047873	36	47	.0053125	17	20	.0058336	14	15
.0042971	11	16	.0047968	33	43	.0053194	40	47	.0058466	29	31
.0043104	20	29	.0048074	30	39	.0053242	23	27	.0058512	44	47
.0043268	27	39	.0048384	24	31	.0053364	35	41	.0058599	15	16
.0043368	34	49	.004847	38	49	.0053572	42	49	.0058674	46	49
.0043477	16	23	.0048613	14	18	.0053572	18	21	.005871	31	33
.0043562	23	33	.0048613	21	27	.0053781	37	43	.0058825	16	17
.0043605	30	43	.0048782	32	41	.005388	25	29	.0059027	17	18
.004375	14	20	.0048912	18	23	.0054057	32	37	.0059122	35	37
.0043883	33	47	.0048989	29	37	.005417	13	15	.0059215	18	19
.0043922	26	37	.0049202	37	47	.0054348	20	23	.0059294	37	39
.004398	19	27	.0049244	26	33	.0054434	27	31	.0059375	19	20
.0044119	12	17	.0049345	15	19	.0054486	34	39	.0059455	39	41
.004421	29	41	.004942	34	43	.0054522	41	47	.0059524	20	21
.0044354	22	31	.0049569	23	29	.005469	14	16	.0059598	41	43
.0044643	15	21	.0049677	31	39	.0054848	43	49	.0059782	22	23
.0044643	35	49	.0049745	39	49	.0054878	36	41	.0059841	45	47
.0044871	28	39	.005	16	20	.0054924	29	33	.0059951	47	49
.004506	31	43	.005	12	15	.0055148	15	17	.0060188	26	27
.004514	13	18	.0050308	33	41	.0055238	38	43	.0060346	28	29
.0045213	34	47	.0050402	25	31	.0055555	24	27	.006048	30	31
.0045259	21	29	.0050532	38	47	.0055555	16	18	.0060607	32	33
.0045452	24	33	.0050596	17	21	.0055746	33	37	.0060812	36	37
.004561	27	37	.0050676	30	37	.0055852	42	47	.0060898	38	39
.0045732	30	41	.0050785	13	16	.0055925	17	19	.006098	40	41
.0045835	11	15	.0050876	35	43	.0056035	26	29	.0061052	42	43
.004592	36	49	.0050928	22	27	.0056088	35	39	.0061171	46	47
.0046055	14	19	.0051022	40	49	.0056123	44	49	.0061224	48	49
.0046194	17	23	.0051136	27	33	.005625	18	20	.00625		1
.0046296	20	27	.0051281	32	39	.0056403	37	41			
.0046371	23	31	.0051474	14	17	.005645	28	31			
.0046473	29	39	.0051627	19	23	.0056546	19	21			
.0046512	32	43	.0051721	24	29	.005669	39	43			
.0046543	35	47	.005183	34	41	.0056816	30	33			
.0046875	15	20	.0051861	39	47	.0057065	21	23			
.0046875	12	16	.0052083	15	18	.005718	43	47			
.0047195	37	49	.0052296	41	49	.00574	45	49			

For method of using the above table see pages 183 and 184.

TABLE OF TOOTH PARTS

CIRCULAR PITCH IN FIRST COLUMN

Circular Pitch.	Threads or Teeth per inch Linear.	Diametral Pitch.	Thickness of Tooth on Pitch Line.	Addendum and Module.	Working Depth of Tooth.	Depth of Space below Pitch Line.	Whole Depth of Tooth.	Width of Thread-Tool at End.	Width of Thread at Top.
P'	$\frac{1}{P'}$	P	t	s	D''	s+f	D'+f	P'x.3095	P'x.3354
2	$\frac{1}{2}$	1.5708	1.0000	.6366	1.2732	.7366	1.3732	.6190	.6707
$1\frac{7}{8}$	$\frac{8}{15}$	1.6755	.9375	.5968	1.1937	.6906	1.2874	.5803	.6288
$1\frac{3}{4}$	$\frac{4}{7}$	1.7952	.8750	.5570	1.1141	.6445	1.2016	.5416	.5869
$1\frac{5}{8}$	$\frac{8}{13}$	1.9333	.8125	.5173	1.0345	.5985	1.1158	.5029	.5450
$1\frac{1}{2}$	$\frac{2}{3}$	2.0944	.7500	.4775	.9549	.5525	1.0299	.4642	.5030
$1\frac{7}{16}$	$\frac{16}{23}$	2.1855	.7187	.4576	.9151	.5294	.9870	.4449	.4821
$1\frac{3}{8}$	$\frac{8}{11}$	2.2848	.6875	.4377	.8754	.5064	.9441	.4256	.4611
$1\frac{1}{3}$	$\frac{3}{4}$	2.3562	.6666	.4244	.8488	.4910	.9154	.4127	.4471
$1\frac{5}{16}$	$\frac{16}{21}$	2.3936	.6562	.4178	.8356	.4834	.9012	.4062	.4402
$1\frac{1}{4}$	$\frac{4}{5}$	2.5133	.6250	.3979	.7958	.4604	.8583	.3869	.4192
$1\frac{3}{16}$	$\frac{16}{19}$	2.6456	.5937	.3780	.7560	.4374	.8154	.3675	.3982
$1\frac{1}{8}$	$\frac{8}{9}$	2.7925	.5625	.3581	.7162	.4143	.7724	.3482	.3773
$1\frac{1}{16}$	$\frac{16}{17}$	2.9568	.5312	.3382	.6764	.3913	.7295	.3288	.3563
1	1	3.1416	.5000	.3183	.6366	.3683	.6866	.3095	.3354
$\frac{15}{16}$	$1\frac{1}{15}$	3.3510	.4687	.2984	.5968	.3453	.6437	.2902	.3144
$\frac{7}{8}$	$1\frac{1}{7}$	3.5904	.4375	.2785	.5570	.3223	.6007	.2708	.2934
$\frac{13}{16}$	$1\frac{3}{13}$	3.8666	.4062	.2586	.5173	.2993	.5579	.2515	.2725
$\frac{4}{5}$	$1\frac{1}{4}$	3.9270	.4000	.2546	.5092	.2946	.5492	.2476	.2683
$\frac{3}{4}$	$1\frac{1}{3}$	4.1888	.3750	.2387	.4775	.2762	.5150	.2321	.2515
$\frac{11}{16}$	$1\frac{5}{11}$	4.5696	.3437	.2189	.4377	.2532	.4720	.2128	.2306
$\frac{3}{5}$	$1\frac{1}{2}$	4.7124	.3333	.2122	.4244	.2455	.4577	.2063	.2236
$\frac{5}{8}$	$1\frac{3}{5}$	5.0265	.3125	.1989	.3979	.2301	.4291	.1934	.2096
$\frac{5}{6}$	$1\frac{2}{3}$	5.2360	.3000	.1910	.3820	.2210	.4120	.1857	.2012
$\frac{4}{7}$	$1\frac{3}{4}$	5.4978	.2857	.1819	.3638	.2105	.3923	.1769	.1916
$\frac{9}{16}$	$1\frac{7}{9}$	5.5851	.2812	.1790	.3581	.2071	.3862	.1741	.1886

TABLE OF TOOTH PARTS—CONTINUED

CIRCULAR PITCH IN FIRST COLUMN

Circular Pitch.	Threads or Teeth per inch Linear.	Diametral Pitch.	Thickness of Tooth on Pitch Line.	Addendum and Module.	Working Depth of Tooth.	Depth of Space below Pitch Line.	Whole Depth of Tooth.	Width of Thread-Tool at End.	Width of Thread at Top.
P'	$\frac{1}{P''}$	P	t	s	D''	s+f	D'+f.	P'x.3095	P'x.3354
$\frac{1}{2}$	2	6.2832	.2500	.1592	.3183	.1842	.3433	.1547	.1677
$\frac{4}{9}$	2 $\frac{1}{4}$	7.0685	.2222	.1415	.2830	.1637	.3052	.1376	.1490
$\frac{7}{16}$	2 $\frac{3}{7}$	7.1808	.2187	.1393	.2785	.1611	.3003	.1354	.1467
$\frac{3}{7}$	2 $\frac{1}{3}$	7.3304	.2143	.1364	.2728	.1578	.2942	.1326	.1437
$\frac{2}{5}$	2 $\frac{1}{2}$	7.8540	.2000	.1273	.2546	.1473	.2746	.1238	.1341
$\frac{3}{8}$	2 $\frac{3}{8}$	8.3776	.1875	.1194	.2387	.1381	.2575	.1161	.1258
$\frac{4}{11}$	2 $\frac{3}{4}$	8.6394	.1818	.1158	.2316	.1340	.2498	.1125	.1219
$\frac{1}{3}$	3	9.4248	.1666	.1061	.2122	.1228	.2289	.1032	.1118
$\frac{6}{16}$	3 $\frac{1}{8}$	10.0531	.1562	.0995	.1989	.1151	.2146	.0967	.1048
$\frac{3}{10}$	3 $\frac{1}{3}$	10.4719	.1500	.0955	.1910	.1105	.2060	.0928	.1006
$\frac{3}{7}$	3 $\frac{1}{2}$	10.9956	.1429	.0909	.1819	.1052	.1962	.0884	.0958
$\frac{1}{4}$	4	12.5664	.1250	.0796	.1591	.0921	.1716	.0774	.0838
$\frac{3}{9}$	4 $\frac{1}{3}$	14.1372	.1111	.0707	.1415	.0818	.1526	.0688	.0745
$\frac{1}{5}$	5	15.7080	.1000	.0637	.1273	.0737	.1373	.0619	.0671
$\frac{3}{16}$	5 $\frac{1}{8}$	16.7552	.0937	.0597	.1194	.0690	.1287	.0580	.0629
$\frac{3}{11}$	5 $\frac{1}{2}$	17.2788	.0909	.0579	.1158	.0670	.1249	.0563	.0610
$\frac{1}{6}$	6	18.8496	.0833	.0531	.1061	.0614	.1144	.0516	.0559
$\frac{3}{13}$	6 $\frac{1}{3}$	20.4203	.0769	.0489	.0978	.0566	.1055	.0476	.0516
$\frac{1}{7}$	7	21.9911	.0714	.0455	.0910	.0526	.0981	.0442	.0479
$\frac{3}{15}$	7 $\frac{1}{2}$	23.5619	.0666	.0425	.0850	.0492	.0917	.0413	.0447
$\frac{1}{8}$	8	25.1327	.0625	.0398	.0796	.0460	.0858	.0387	.0419
$\frac{1}{9}$	9	28.2743	.0555	.0354	.0707	.0409	.0763	.0344	.0373
$\frac{1}{10}$	10	31.4159	.0500	.0318	.0637	.0368	.0687	.0309	.0335
$\frac{1}{16}$	16	50.2655	.0312	.0199	.0398	.0230	.0429	.0193	.0210
$\frac{1}{20}$	20	62.8318	.0250	.0159	.0318	.0184	.0343	.0155	.0168

TABLE OF TOOTH PARTS

DIAMETRAL PITCH IN FIRST COLUMN

Diametral Pitch.	Circular Pitch.	Thickness of Tooth on Pitch Line.	Addendum and Module.	Working Depth of Tooth.	Depth of Space below Pitch Line.	Whole Depth of Tooth.
P	P'	t	s	D''	s + f.	D'' + f.
$\frac{1}{2}$	6.2832	3.1416	2.0000	4.0000	2.3142	4.3142
$\frac{3}{4}$	4.1888	2.0944	1.3333	2.6666	1.5428	2.8761
1	3.1416	1.5708	1.0000	2.0000	1.1571	2.1571
$1\frac{1}{4}$	2.5133	1.2566	.8000	1.6000	.9257	1.7257
$1\frac{1}{2}$	2.0944	1.0472	.6666	1.3333	.7714	1.4381
$1\frac{3}{4}$	1.7952	.8976	.5714	1.1429	.6612	1.2326
2	1.5708	.7854	.5000	1.0000	.5785	1.0785
$2\frac{1}{4}$	1.3963	.6981	.4444	.8888	.5143	.9587
$2\frac{1}{2}$	1.2566	.6283	.4000	.8000	.4628	.8628
$2\frac{3}{4}$	1.1424	.5712	.3636	.7273	.4208	.7844
3	1.0472	.5236	.3333	.6666	.3857	.7190
$3\frac{1}{2}$	.8976	.4488	.2857	.5714	.3306	.6163
4	.7854	.3927	.2500	.5000	.2893	.5393
5	.6283	.3142	.2000	.4000	.2314	.4314
6	.5236	.2618	.1666	.3333	.1928	.3595
7	.4488	.2244	.1429	.2857	.1653	.3081
8	.3927	.1963	.1250	.2500	.1446	.2696
9	.3491	.1745	.1111	.2222	.1286	.2397
10	.3142	.1571	.1000	.2000	.1157	.2157
11	.2856	.1428	.0909	.1818	.1052	.1961
12	.2618	.1309	.0833	.1666	.0964	.1798
13	.2417	.1208	.0769	.1538	.0890	.1659
14	.2244	.1122	.0714	.1429	.0826	.1541

TABLE OF TOOTH PARTS—CONTINUED

DIAMETRAL PITCH IN FIRST COLUMN

Diametral Pitch.	Circular Pitch.	Thickness of Tooth on Pitch Line.	$\frac{1}{P}$ or the Addendum or Module.	Working Depth of Tooth.	Depth of Space below Pitch Line.	Whole Depth of Tooth.
P.	P'.	t.	s.	D''.	s+f.	D''+f.
15	.2094	.1047	.0666	.1333	.0771	.1438
16	.1963	.0982	.0625	.1250	.0723	.1348
17	.1848	.0924	.0588	.1176	.0681	.1269
18	.1745	.0873	.0555	.1111	.0643	.1198
19	.1653	.0827	.0526	.1053	.0609	.1135
20	.1571	.0785	.0500	.1000	.0579	.1079
22	.1428	.0714	.0455	.0909	.0526	.0980
24	.1309	.0654	.0417	.0833	.0482	.0898
26	.1208	.0604	.0385	.0769	.0445	.0829
28	.1122	.0561	.0357	.0714	.0413	.0770
30	.1047	.0524	.0333	.0666	.0386	.0719
32	.0982	.0491	.0312	.0625	.0362	.0674
34	.0924	.0462	.0294	.0588	.0340	.0634
36	.0873	.0436	.0278	.0555	.0321	.0599
38	.0827	.0413	.0263	.0526	.0304	.0568
40	.0785	.0393	.0250	.0500	.0289	.0539
42	.0748	.0374	.0238	.0476	.0275	.0514
44	.0714	.0357	.0227	.0455	.0263	.0490
46	.0683	.0341	.0217	.0435	.0252	.0469
48	.0654	.0327	.0208	.0417	.0241	.0449
50	.0628	.0314	.0200	.0400	.0231	.0431
56	.0561	.0280	.0178	.0357	.0207	.0385
60	.0524	.0262	.0166	.0333	.0193	.0360

**TABLE GIVING CHORDAL THICKNESS OF GEAR TEETH (t')
AND DISTANCE FROM CHORD TO TOP OF TOOTH (s')**

NUMBER OF TEETH	t'	s'	NUMBER OF TEETH	t'	s'	NUMBER OF TEETH	t'	s'
						94	1.5707	1.0066
6	1.5529	1.1022	50	1.5705	1.0123	95	1.5707	1.0065
7	1.5568	1.0873	51	1.5706	1.0121	96	1.5707	1.0064
8	1.5607	1.0769	52	1.5706	1.0119	97	1.5707	1.0064
9	1.5628	1.0684	53	1.5706	1.0117	98	1.5707	1.0063
10	1.5643	1.0616	54	1.5706	1.0114	99	1.5707	1.0062
11	1.5654	1.0559	55	1.5706	1.0112	100	1.5707	1.0061
12	1.5663	1.0514	56	1.5706	1.0110	101	1.5707	1.0061
13	1.5670	1.0474	57	1.5706	1.0108	102	1.5707	1.0060
14	1.5675	1.0440	58	1.5706	1.0106	103	1.5707	1.0060
15	1.5679	1.0411	59	1.5706	1.0105	104	1.5707	1.0059
16	1.5683	1.0385	60	1.5706	1.0102	105	1.5707	1.0059
17	1.5686	1.0362	61	1.5706	1.0101	106	1.5707	1.0058
18	1.5688	1.0342	62	1.5706	1.0100	107	1.5707	1.0058
19	1.5690	1.0324	63	1.5706	1.0098	108	1.5707	1.0057
20	1.5692	1.0308	64	1.5706	1.0097	109	1.5707	1.0057
21	1.5694	1.0294	65	1.5706	1.0095	110	1.5707	1.0056
22	1.5695	1.0281	66	1.5706	1.0094	111	1.5707	1.0056
23	1.5696	1.0268	67	1.5706	1.0092	112	1.5707	1.0055
24	1.5697	1.0257	68	1.5706	1.0091	113	1.5707	1.0055
25	1.5698	1.0247	69	1.5707	1.0090	114	1.5707	1.0054
26	1.5698	1.0237	70	1.5707	1.0088	115	1.5707	1.0054
27	1.5699	1.0228	71	1.5707	1.0087	116	1.5707	1.0053
28	1.5700	1.0220	72	1.5707	1.0086	117	1.5707	1.0053
29	1.5700	1.0213	73	1.5707	1.0085	118	1.5707	1.0053
30	1.5701	1.0208	74	1.5707	1.0084	119	1.5707	1.0052
31	1.5701	1.0199	75	1.5707	1.0083	120	1.5707	1.0052
32	1.5702	1.0193	76	1.5707	1.0081	121	1.5707	1.0051
33	1.5702	1.0187	77	1.5707	1.0080	122	1.5707	1.0051
34	1.5702	1.0181	78	1.5707	1.0079	123	1.5707	1.0050
35	1.5702	1.0176	79	1.5707	1.0078	124	1.5707	1.0050
36	1.5703	1.0171	80	1.5707	1.0077	125	1.5707	1.0049
37	1.5703	1.0167	81	1.5707	1.0076	126	1.5707	1.0049
38	1.5703	1.0162	82	1.5707	1.0075	127	1.5707	1.0049
39	1.5704	1.0158	83	1.5707	1.0074	128	1.5707	1.0048
40	1.5704	1.0154	84	1.5707	1.0074	129	1.5707	1.0048
41	1.5704	1.0150	85	1.5707	1.0073	130	1.5707	1.0047
42	1.5704	1.0147	86	1.5707	1.0072	131	1.5708	1.0047
43	1.5705	1.0143	87	1.5707	1.0071	132	1.5708	1.0047
44	1.5705	1.0140	88	1.5707	1.0070	133	1.5708	1.0047
45	1.5705	1.0137	89	1.5707	1.0069	134	1.5708	1.0046
46	1.5705	1.0134	90	1.5707	1.0068	135	1.5708	1.0046
47	1.5705	1.0131	91	1.5707	1.0068	150	1.5708	1.0045
48	1.5705	1.0129	92	1.5707	1.0067	250	1.5708	1.0025
49	1.5705	1.0126	93	1.5707	1.0067	RACK	1.5708	1.0000

TABLE FOR OBTAINING SET-OVER FOR CUTTING BEVEL GEARS

RATIO OF APEX DISTANCE TO WIDTH OF FACE = $\frac{\text{APEX}}{\text{FACE}}$

NO. OF CUTTER	3 1	3¼ 1	3½ 1	3¾ 1	4 1	4¼ 1	4½ 1	4¾ 1	5 1	5½ 1	6 1	7 1	8 1
1	.254	.254	.255	.256	.257	.257	.257	.258	.258	.259	.260	.262	.264
2	.266	.268	.271	.272	.273	.274	.274	.275	.277	.279	.280	.283	.284
3	.266	.268	.271	.273	.275	.278	.280	.282	.283	.286	.287	.290	.292
4	.275	.280	.285	.287	.291	.293	.296	.298	.298	.302	.305	.308	.311
5	.280	.285	.290	.293	.295	.296	.298	.300	.302	.307	.309	.313	.315
6	.311	.318	.323	.328	.330	.334	.337	.340	.343	.348	.352	.356	.362
7	.289	.298	.308	.316	.324	.329	.334	.338	.343	.350	.360	.370	.376
8	.275	.286	.296	.309	.319	.331	.338	.344	.352	.361	.368	.380	.386

TABLE OF CUTTERS, PITCHES, GEARS AND ANGLES FOR TWIST DRILLS

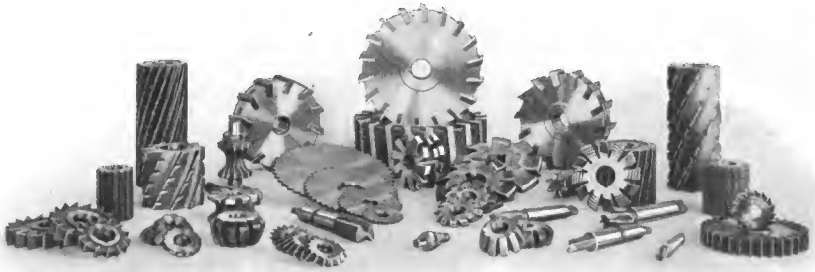
DIAMETER OF DRILL	THICKNESS OF CUTTER	PITCH IN INCHES	GEAR ON WORM	FIRST GEAR ON STUD	SECOND GEAR ON STUD	GEAR ON SCREW	ANGLE OF SPIRAL
$\frac{1}{16}$	.06	.67	24	86	24	100	16° 20'
$\frac{1}{8}$	.08	1.12	24	86	40	100	19° 20'
$\frac{3}{16}$	.11	1.67	24	64	32	72	19° 25'
$\frac{1}{4}$	.15	1.94	32	64	28	72	21°
$\frac{5}{16}$	.19	2.92	24	64	56	72	20°
$\frac{3}{8}$	.23	3.24	40	48	28	72	21°
$\frac{7}{16}$	.27	3.89	56	48	24	72	20° 10'
$\frac{1}{2}$	.31	4.17	40	72	48	64	20° 30'
$\frac{9}{16}$	.35	4.86	40	64	56	72	20°
$\frac{5}{8}$	.39	5.33	48	40	32	72	20° 12'
$\frac{11}{16}$	.44	6.12	56	40	28	64	19° 30'
$\frac{3}{4}$	.50	6.48	56	48	40	72	20°
$\frac{13}{16}$	.56	7.29	56	48	40	64	19° 20'
$\frac{7}{8}$	.62	7.62	64	48	32	56	19° 50'
$\frac{15}{16}$	.70	8.33	48	32	40	72	19° 30'
1	.77	8.95	86	48	28	56	19° 20'
$1\frac{1}{8}$	.85	9.33	56	40	48	72	20° 40'

TABLE OF CUTTING SPEEDS

FT. PER MINUTE	15	17.5	20	22.5	25	27.5	30	35	40	45	50	55
DIAM.	REVOLUTIONS PER MINUTE											
1/16	917	1070	1222	1375	1528	1681	1833	2139	2445	2750	3056	3361
1/8	458	535	611	688	764	840	917	1070	1222	1375	1528	1681
3/16	306	357	407	458	509	560	611	713	815	917	1019	1120
1/4	229	267	306	344	382	420	458	535	611	688	764	840
5/16	183	214	244	275	306	336	367	428	489	550	611	672
3/8	153	178	204	229	255	280	306	357	407	458	509	560
7/16	131	153	175	196	218	240	262	306	349	393	437	480
1/2	115	134	153	172	191	210	229	267	306	344	382	420
5/8	91.7	107	122	138	153	168	183	214	244	275	306	336
3/4	76.4	89.1	102	115	127	140	153	178	204	229	255	280
7/8	65.5	76.4	87.3	98.2	109	120	131	153	175	196	218	240
1	57.3	66.8	76.4	85.9	95.5	105	115	134	153	172	191	210
1 1/8	50.9	59.4	67.9	76.4	84.9	93.4	102	119	136	153	170	187
1 1/4	45.8	53.5	61.1	68.8	76.4	84.0	91.7	107	122	138	153	168
1 3/8	41.7	48.6	55.6	62.5	69.5	76.4	83.3	97.2	111	125	139	153
1 1/2	38.2	44.6	50.9	57.3	63.7	70.0	76.4	89.1	102	115	127	140
1 5/8	35.3	41.1	47.0	52.9	58.8	64.6	70.5	82.3	94.0	106	118	129
1 3/4	32.7	38.2	43.7	49.1	54.6	60.0	65.5	76.4	87.3	98.2	109	120
1 7/8	30.6	35.7	40.7	45.8	50.9	56.0	61.1	71.3	81.5	91.7	102	112
2	28.7	33.4	38.2	43.0	47.7	52.5	57.3	66.8	76.4	85.9	95.5	105
2 1/4	25.5	29.7	34.0	38.2	42.4	46.7	50.9	59.4	67.9	76.4	84.9	93.4
2 1/2	22.9	26.7	30.6	34.4	38.2	42.0	45.8	53.5	61.1	68.8	76.4	84.0
2 3/4	20.8	24.3	27.8	31.3	34.7	38.2	41.7	48.6	55.6	62.5	69.5	76.4
3	19.1	22.3	25.5	28.6	31.8	35.0	38.2	44.6	50.9	57.3	63.7	70.0
3 1/4	17.6	20.6	23.5	26.4	29.4	32.3	35.3	41.1	47.0	52.9	58.8	64.6
3 1/2	16.4	19.1	21.8	24.5	27.3	30.0	32.7	38.2	43.7	49.1	54.6	60.0
3 3/4	15.3	17.8	20.4	22.9	25.5	28.0	30.6	35.7	40.7	45.8	50.9	56.0
4	14.3	16.7	19.1	21.5	23.9	26.3	28.7	33.4	38.2	43.0	47.7	52.5
4 1/2	12.7	14.9	17.0	19.1	21.2	23.3	25.5	29.7	34.0	38.2	42.4	46.7
5	11.5	13.4	15.3	17.2	19.1	21.0	22.9	26.7	30.6	34.4	38.2	42.0
5 1/2	10.4	12.2	13.9	15.6	17.4	19.1	20.8	24.3	27.8	31.3	34.7	38.2
6	9.5	11.1	12.7	14.3	15.9	17.5	19.1	22.3	25.5	28.6	31.8	35.0
6 1/2	8.8	10.3	11.8	13.2	14.7	16.2	17.6	20.6	23.5	26.4	29.4	32.3
7	8.2	9.5	10.9	12.3	13.6	15.0	16.4	19.1	21.8	24.5	27.3	30.0
7 1/2	7.6	8.9	10.2	11.5	12.7	14.0	15.3	17.8	20.4	22.9	25.5	28.0
8	7.2	8.4	9.5	10.7	11.9	13.1	14.3	16.7	19.1	21.5	23.9	26.3
8 1/2	6.7	7.9	9.0	10.1	11.2	12.4	13.5	15.7	18.0	20.2	22.5	24.7
9	6.4	7.4	8.5	9.5	10.6	11.7	12.7	14.9	17.0	19.1	21.2	23.3
9 1/2	6.0	7.0	8.0	9.1	10.1	11.1	12.1	14.1	16.1	18.1	20.1	22.1
10	5.7	6.7	7.6	8.6	9.5	10.5	11.5	13.4	15.3	17.2	19.1	21.0
11	5.2	6.1	6.9	7.8	8.7	9.5	10.4	12.2	13.9	15.6	17.4	19.1
12	4.8	5.6	6.4	7.2	8.0	8.8	9.5	11.1	12.7	14.3	15.9	17.5
13	4.4	5.1	5.9	6.6	7.3	8.1	8.8	10.3	11.8	13.2	14.7	16.2
14	4.1	4.8	5.5	6.1	6.8	7.5	8.2	9.5	10.9	12.3	13.6	15.0
15	3.8	4.5	5.1	5.7	6.4	7.0	7.6	8.9	10.2	11.5	12.7	14.0
16	3.6	4.2	4.8	5.4	6.0	6.6	7.2	8.4	9.5	10.7	11.9	13.1
17	3.4	3.9	4.5	5.1	5.6	6.2	6.7	7.9	9.0	10.1	11.2	12.4
18	3.2	3.7	4.2	4.8	5.3	5.8	6.4	7.4	8.5	9.5	10.6	11.7
	15	17.5	20	22.5	25	27.5	30	35	40	45	50	55

TABLE OF CUTTING SPEEDS—CONTINUED

FT. PER MINUTE	60	65	70	75	80	90	100	110	120	130	140	150
DIAM.	REVOLUTIONS PER MINUTE											
1/16	3667	3973	4278	4584	4889							
1/8	1833	1986	2139	2292	2445	2750	3056	3361	3667	3973	4278	4584
3/16	1222	1324	1426	1528	1630	1833	2037	2241	2445	2648	2852	3056
1/4	917	993	1070	1146	1222	1375	1528	1681	1833	1986	2139	2292
5/16	733	794	856	917	978	1100	1222	1345	1467	1589	1711	1833
3/8	611	662	713	764	815	917	1019	1120	1222	1324	1426	1528
7/16	524	568	611	655	698	786	873	960	1048	1135	1222	1310
1/2	458	497	535	573	611	688	764	840	917	993	1070	1146
5/8	367	397	428	458	489	550	611	672	733	794	856	917
3/4	306	331	357	382	407	458	509	560	611	662	713	764
7/8	262	284	306	327	349	393	437	480	524	568	611	655
1	229	248	267	287	306	344	382	420	458	497	535	573
1 1/8	204	221	238	255	272	306	340	373	407	441	475	509
1 1/4	183	199	214	229	244	275	306	336	367	397	428	458
1 3/8	167	181	194	208	222	250	278	306	333	361	389	417
1 1/2	153	166	178	191	204	229	255	280	306	331	357	382
1 5/8	141	153	165	176	188	212	235	259	282	306	329	353
1 3/4	131	142	153	164	175	196	218	240	262	284	306	327
1 7/8	122	132	143	153	163	183	204	224	244	265	285	306
2	115	124	134	143	153	172	191	210	229	248	267	287
2 1/4	102	110	119	127	136	153	170	187	204	221	238	255
2 1/2		91.7	107	115	122	138	153	168	183	199	214	229
2 3/4	83.3	90.3	97.2	104	111	125	139	153	167	181	194	208
3	76.4	82.8	89.1	95.5	102	115	127	140	153	166	178	191
3 1/4	70.5	76.4	82.3	88.2	94.0	106	118	129	141	153	165	176
3 1/2	65.5	70.9	76.4	81.9	87.3	98.2	109	120	131	142	153	164
3 3/4	61.1	66.2	71.3	76.4	81.5	91.7	102	112	122	132	143	153
4	57.3	62.1	66.8	71.6	76.4	85.9	95.5	105	115	124	134	143
4 1/2	50.9	55.2	59.4	63.6	67.9	76.4	84.9	93.4	102	110	119	127
5	45.8	49.7	53.5	57.3	61.1	68.8	76.4	84.0	91.7	99.3	107	115
5 1/2	41.7	45.1	48.6	52.1	55.6	62.5	69.5	76.4	83.3	90.3	97.2	104
6	38.2	41.4	44.6	47.8	50.9	57.3	63.7	70.0	76.4	82.8	89.1	95.5
6 1/2	35.3	38.2	41.1	44.1	47.0	52.9	58.8	64.6	70.5	76.4	82.3	88.2
7	32.7	35.5	38.2	40.9	43.7	49.1	54.6	60.0	65.5	70.9	76.4	81.9
7 1/2	30.6	33.1	35.7	38.2	40.7	45.8	50.9	56.0	61.1	66.2	71.3	76.4
8	28.7	31.0	33.4	35.8	38.2	43.0	47.7	52.5	57.3	62.1	66.8	71.6
8 1/2	27.0	29.2	31.5	33.7	36.0	40.4	44.9	49.4	53.9	58.4	62.9	67.4
9	25.5	27.6	29.7	31.8	34.0	38.2	42.4	46.7	50.9	55.2	59.4	63.6
9 1/2	24.1	26.1	28.2	30.2	32.2	36.2	40.2	44.2	48.3	52.3	56.3	60.3
10	22.9	24.8	26.7	28.7	30.6	34.4	38.2	42.0	45.8	49.7	53.5	57.3
11	20.8	22.6	24.3	26.0	27.8	31.3	34.7	38.2	41.7	45.1	48.6	52.1
12	19.1	20.7	22.3	23.9	25.5	28.6	31.8	35.0	38.2	41.4	44.6	47.8
13	17.6	19.1	20.6	22.0	23.5	26.4	29.4	32.3	35.3	38.2	41.1	44.1
14	16.4	17.7	19.1	20.5	21.8	24.5	27.3	30.0	32.7	35.5	38.2	40.9
15	15.3	16.6	17.8	19.1	20.4	22.9	25.5	28.0	30.6	33.1	35.7	38.2
16	14.3	15.5	16.7	17.9	19.1	21.5	23.9	26.3	28.7	31.0	33.4	35.8
17	13.5	14.6	15.7	16.9	18.0	20.2	22.5	24.7	27.0	29.2	31.5	33.7
18	12.7	13.8	14.9	15.9	17.0	19.1	21.2	23.3	25.5	27.6	29.7	31.8
	60	65	70	75	80	90	100	110	120	130	140	150



Tell Us Your Cutter Difficulties

It matters not whether they are problems of accuracy, production, or length of service. We have probably faced the same situations at some time or other and can readily remedy your troubles. We developed the extensive line of

B. & S. CUTTERS

by experience and study of not only our own requirements, but those of our customers.

The services of our experts in making and running of cutters are always at your command.

B. & S. Cutters fulfill the requirements of quality, accuracy and service. They are carefully made and rigidly inspected in every way before going into stock.

Hardening of cutters is one of the most important steps in their manufacture. After years of experience we have perfected this process to a point where dependable uniform temper and long wearing qualities are assured.

We carry in stock at all times over 45 styles and 5000 sizes of cutters.

If your work requires cutters for cutting special forms, send us a drawing or sample and we will gladly submit estimate of cost of cutters.



No. 2 Cutter
Grinding Machine

Don't Let Your

**Sharp Cutters Give Faster
Production**

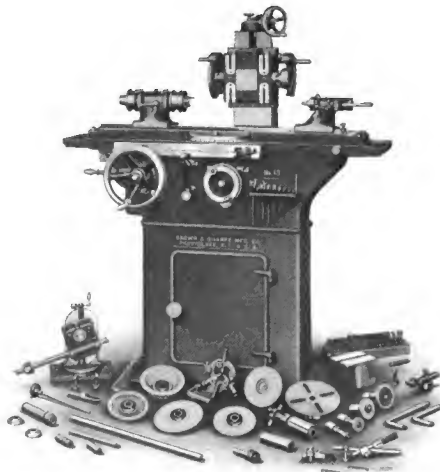
**Sharp Cutters Consume
Less Power**

YOU can sharpen cutters on a cylindrical grinding machine or on a lathe, but it requires too much time to rig up, and ties up a machine that might be more profitably employed.

Ask us for special circulars of our cutter grinding machines.

No. 2 Cutter Grinding Machine

Capacity: Cutters, 6" diameter; 6" length; saws, 24" diameter.



No. 13 Universal and Tool Grinding Machine

Capacity: Centres swing 8" diameter; take 24½" length.

Cutters Get Dull

Sharp Cutters Produce Better Surfaces

Cutters Kept Well Sharpened Wear Longer

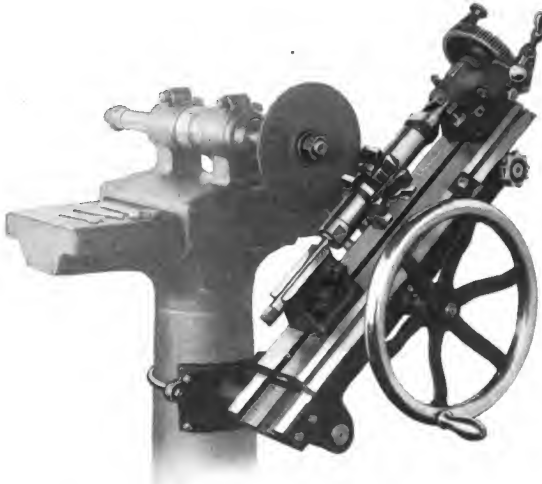
A CUTTER grinding machine provides a quick and easy means of sharpening cutters. In the course of a short time it will pay for itself in any shop. Your production will be greater and your cutter bills less.



No. 3 Universal
Cutter and Reamer
Grinding Machine

No. 3 Universal Cutter and Reamer Grinding Machine

Capacity: 18" between centres; grinds cutters and shell reamers, not exceeding 6" diameter and 7" length.



**Formed Cutter Grinding Attachment
For No. 2 Cutter Grinding Machine and
No. 3 Universal Cutter and Reamer Grinding Machine**

Capacity: Centres swing $4\frac{3}{4}$ " in diameter and take $10\frac{1}{2}$ " in length.

Publications

Treatises

The following books are sent by mail on receipt of prices listed.

Construction and Use of Automatic Screw Machines

Edition of 1918

This book is published to assist those who are not familiar with the construction and use of the Automatic Screw Machine. Illustrated. Cardboard covers, price, 50 cents.

Construction and Use of Universal Grinding Machines

Edition of 1918

This work describes the construction and use of Universal Grinding Machines, as made by us. Illustrated. Cardboard covers, price, 25 cents.

Construction and Use of Plain Grinding Machines

Edition of 1918

This work describes the construction and use of Plain Grinding Machines, as made by us. Illustrated. Cardboard covers, price, 25 cents.

Practical Treatise on Gearing

Edition of 1915

This book, with its tables and illustrations, is written for those who wish to obtain practical explanations and directions in making Gear Wheels. Cloth covers, price, \$1.00; Cardboard covers, price, 75 cents.

Formulas in Gearing

Edition of 1918

This work supplements the "Practical Treatise on Gearing" and contains formulas for solving the problems that occur in gearing. Cloth covers, price, \$1.50.

Hand Book for Apprenticed Machinists

This book, illustrated, is for learners in the use of Machine Tools. The present edition has been carefully revised and enlarged. Cloth covers, price, 50 cents.

Catalogs and Booklets

Any of the following catalogs or booklets are mailed free to any address on receipt of request:

General Catalog (Pocket size, blue covers) **Gear Catalog**

Milling Machine Catalog

Small Tool Catalog

Screw Machine Catalog

Cutter Catalog

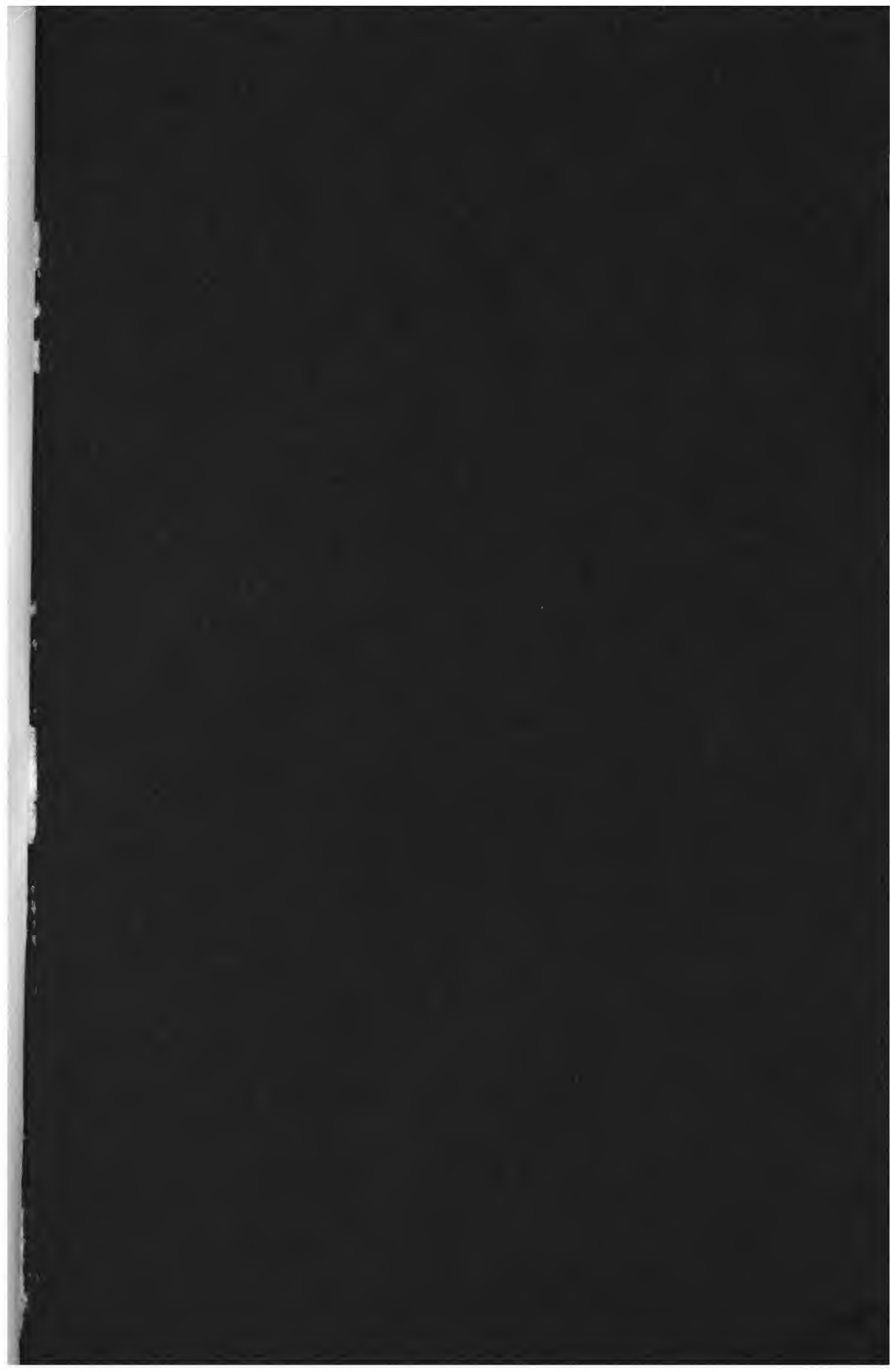
Points About Grinding Wheels and Their Selection

(50-Page Booklet, Pocket Size)

INDEX

	PAGE
Adjustable Index Crank	50
Adjustments	42
Alignments of Milling Machines	22
Angle of Tooth Face on Cutters	100
Angular Cutters	94
Arbors, Method of Driving	108
Attachments	69-87
Cam Cutting	177-182
Cam Cutting Attachment	85
Care of Driving Chain on Motor-Driven Machines	41
Care of Machine	40-43
Centres, Index	72-76
Circular Milling Attachments	80
Classification of Milling Machines	11-20
Clearance on Cutters	106
Column and Knee Milling Machines	11
Cone Drive	17
Constant Speed Drive	18
Counter-shaft	37
Cutter, Direction to Move Work Under	113
Face Milling	93
Fly	95
Plain Milling	89
Side Milling	92
T Slot	94
Cutters	89-106
Angular	94
Clearance on	106
Diameter of	101
Formed	94
Right and Left-Hand	97
Sharpening	104
Temper of	101
Cutting Bevel Gears	153-158
Spiral Gears	159-160
Spirals	58-68
Spur Gears	149-153
Differential Indexing	54
Drive, Cone	17
Constant Speed	18
End Mill	93
Erection and Care of Machine	37-43
Essentials of a Modern Milling Machine	21-35
Face Milling Cutter	93
Fly Cutter	95
Formed Cutters	94
Gang Milling	101
Gear Cutting Attachment	76

	PAGE
Gears, Cutting Bevel	153-158
Gears, Cutting Spiral	159 and 160
Spur	149-153
Graduated Index Sector	49
Graduating	183
High Speed Milling Attachment	82
Horizontal Milling Attachment	80
Index Centres	72-76
Crank, Adjustable	50
Plates and Change Gears	49
Sector, Graduated	49
Indexing	52-58
Inserted Teeth in Cutters	97
Limits in Milling to Size	114
Lubricant	115
Manufacturing Milling Machine	12
Methods of Driving Milling Machines	17-20
Milling Machine, Column and Knee	11
Manufacturing	12
Plain	14
Planer	14
Universal	15
Vertical Spindle	17
Machines, Classification of	11-20
Oil, kind of	41
Original Universal Milling Machine	6
Pickling Castings and Forgings	107
Plain Milling Machine	14
Planer Milling Machine	14
Rack Cutting Attachment	84
Scales and Verniers	87
Side Milling Cutter	92
Sharpening Cutters	104
Short Leads, Attachment for Cutting	83
Slotting Attachment	83
Speeds and Feeds	26 and 103
Spiral Head	47-52
Spiral Milling Attachment	84
Spirals, Cutting	58-68
Spring Chuck	87
Spur Gears, Cutting	149-153
Steel, Carbon and High Speed	89
Straddle Mills	92
Tilting Table	85
T Slot Cutter	94
Universal Milling Attachment	80
Machine	15
Vertical Spindle Milling Attachments	77-79
Machine	17
Vises	71



COLUMBIA UNIVERSITY LIBRARIES

This book is due on the date indicated below, or at the expiration of a definite period after the date of borrowing, as provided by the library rules or by special arrangement with the Librarian in charge.

[illegible]

ENGINEERING

Vol. 2

D 621.91

B815
c. 1

Broconet Sharpe mfg. Co.

Milling & milling machines

This book must be returned to the desk at which it was borrowed before 10 o'clock A. M. the next day, unless special arrangement is made. If this book is not returned by that hour, a fine of 25 cents a day will be incurred.

